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Three-Dimensional Ground-Water Flow Modeling for Management of Water Resources at Lake Mead National Recreation Area

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GeoTrans, Inc.

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Background

- Groundwater production in southern Nevada has primarily been from basin-fill deposits
- Limited production has occurred from the regionally extensive carbonate aquifer

Issue

- The Lake Mead National Recreational Area has responsibility for springs and habitat dependent on groundwater discharge that are threatened by groundwater development
- Nevada has used topographic basins and local recharge estimates to manage a groundwater resource characterized by interbasin flow

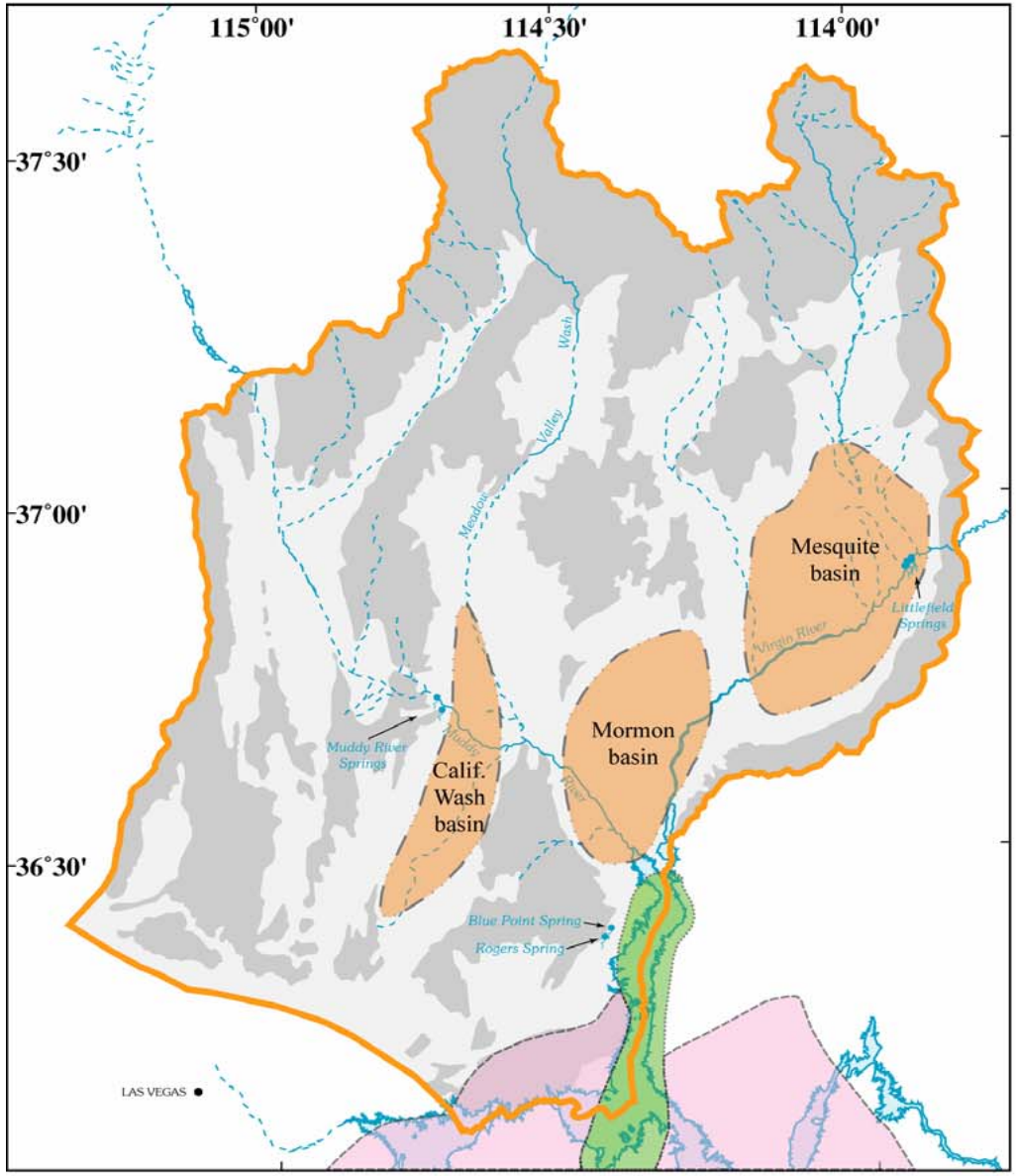
Issue

- Rapid growth of demand for water in Las Vegas and southern Nevada
- The large volume of water stored in the carbonate aquifer is an important resource

Issue

- BUT, the water in storage cannot be pumped without decreasing discharge from the groundwater system
- The relevant questions are
  - Where?
  - How much?
  - What level of reduction is significant?

Thick basin-fill deposits and other relatively impervious rocks



Study Area

Spring

Consolidated Rock

Basin Fill

Thick basin-fill deposits

Subsurface salt body

Area underlain by Tertiary basin fill, Tertiary volcanic and intrusive rock, and Precambrian crystalline basement, undifferentiated

0 20

Miles

Geology modified from Plume and Carlton (1988)

Base modified from USGS digital data, 1:100,000

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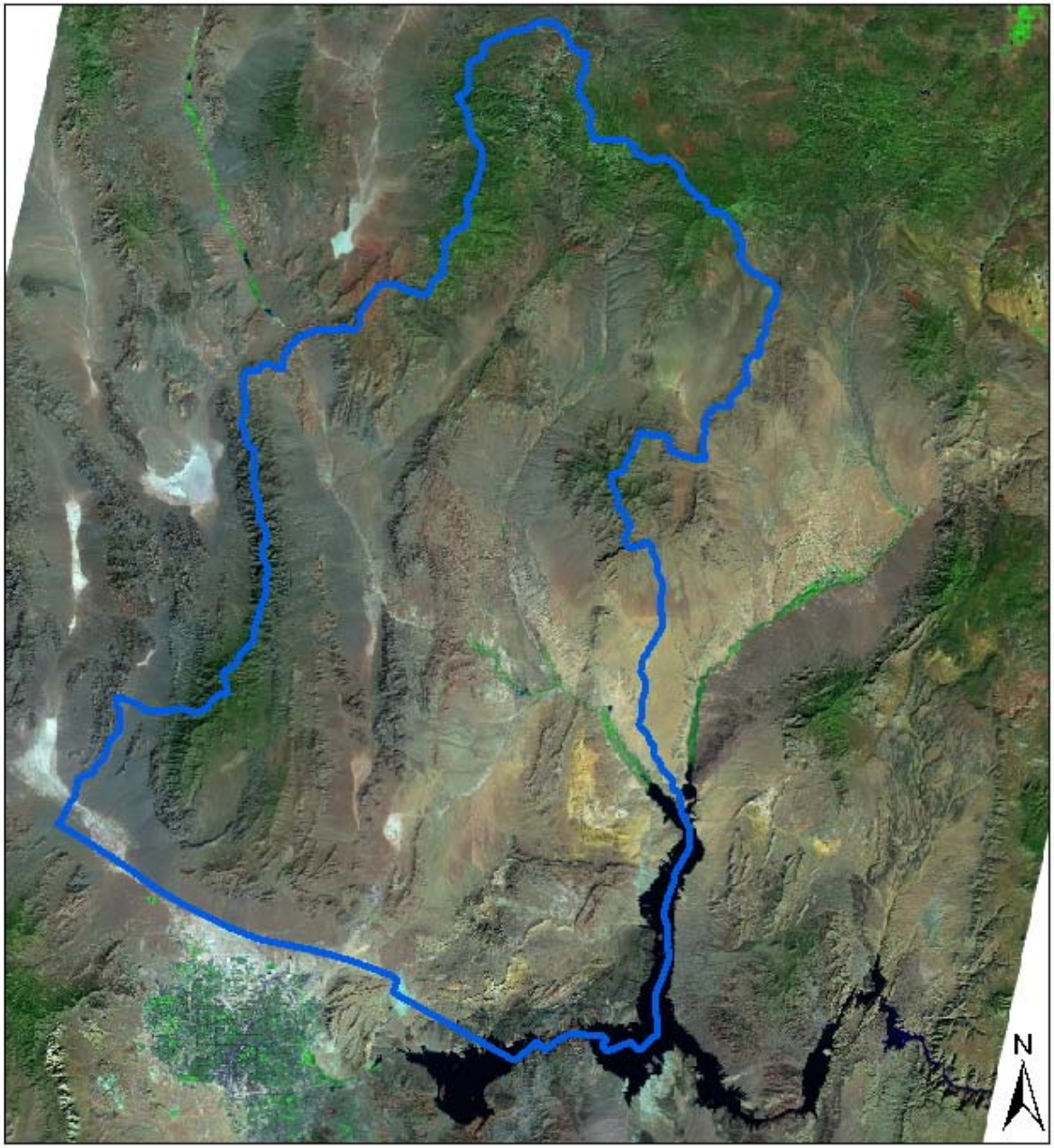

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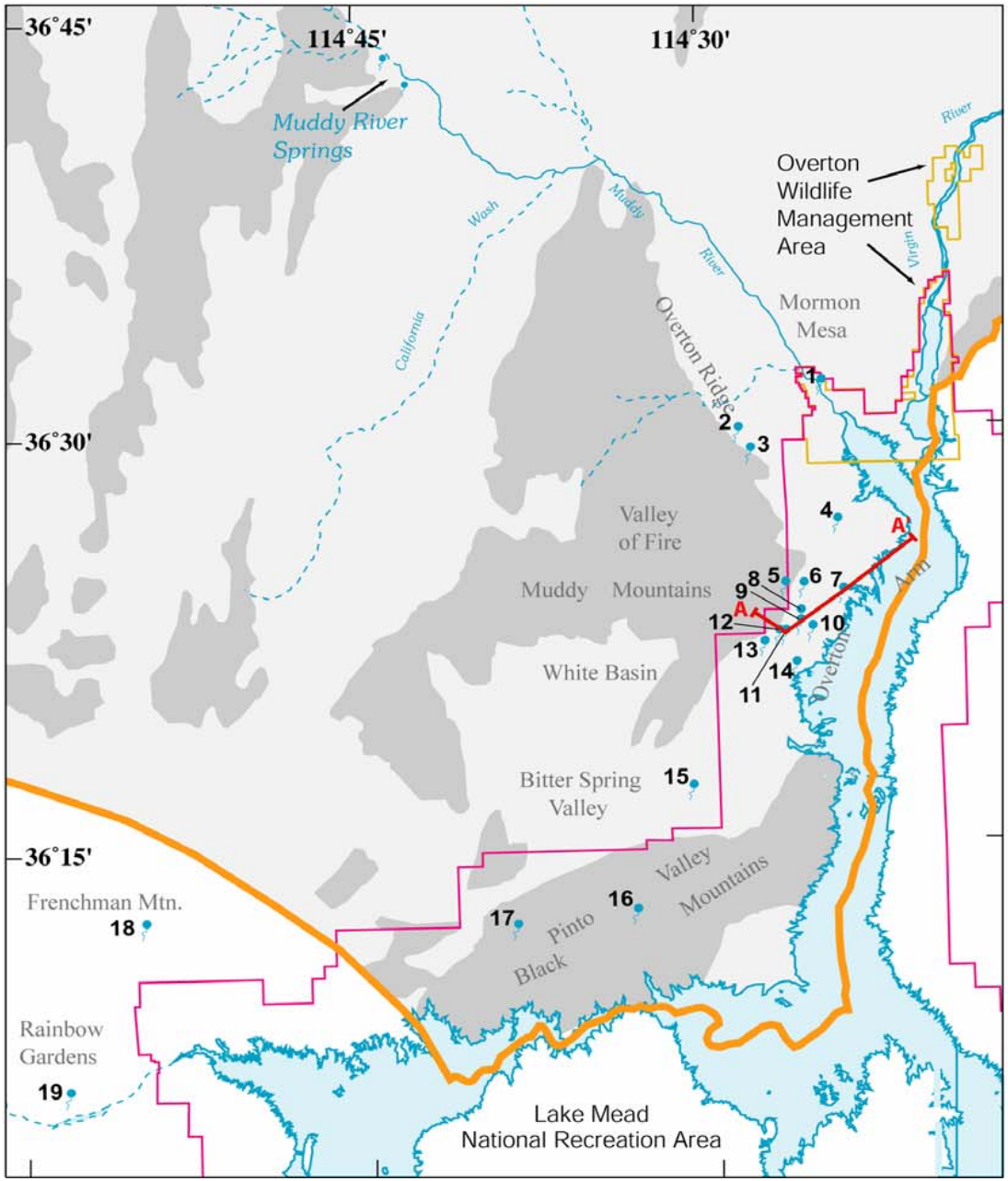
Springs in the Overton Arm Area of Lake Mead



EXPLANATION

- Study Area
- Trace of Cross Section
- Spring 11 – Rogers Spring
  8 - Blue Point Spring
- Consolidated Rock
- Basin Fill

0 10

Miles

Geology modified from Plume and Carlton (1988)

Base modified from USGS digital data, 1:100,000 and USGS GAP Analysis data.

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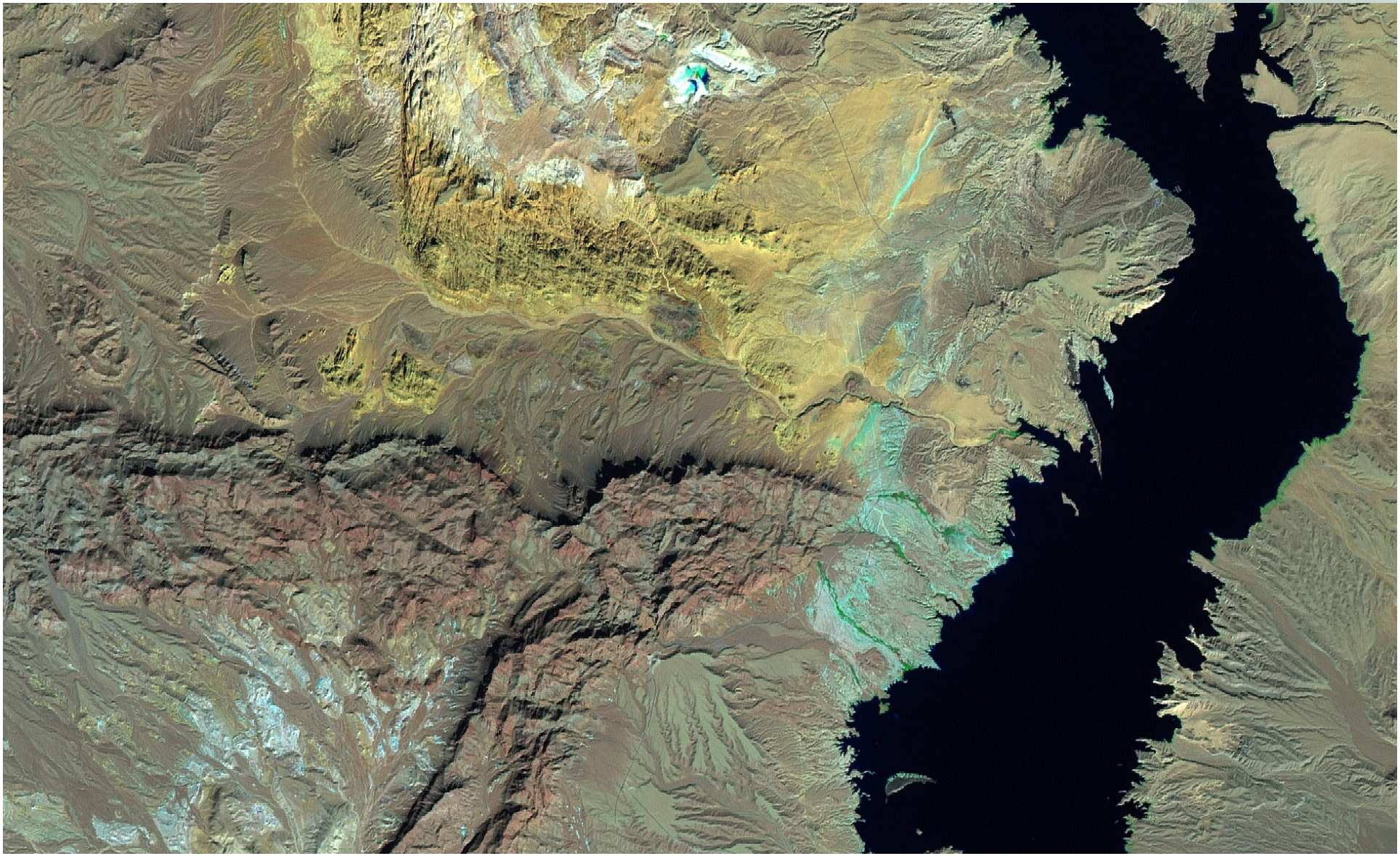

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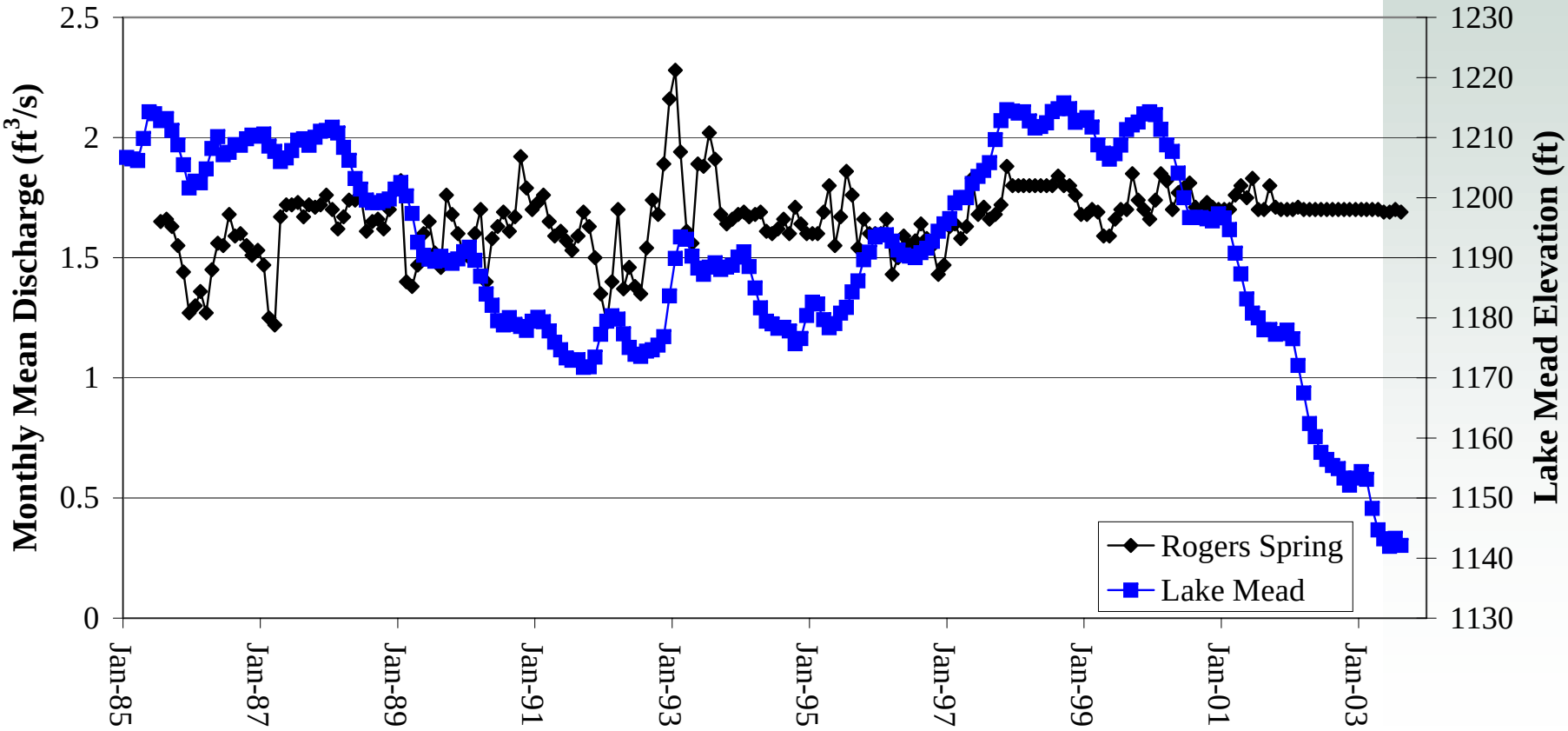
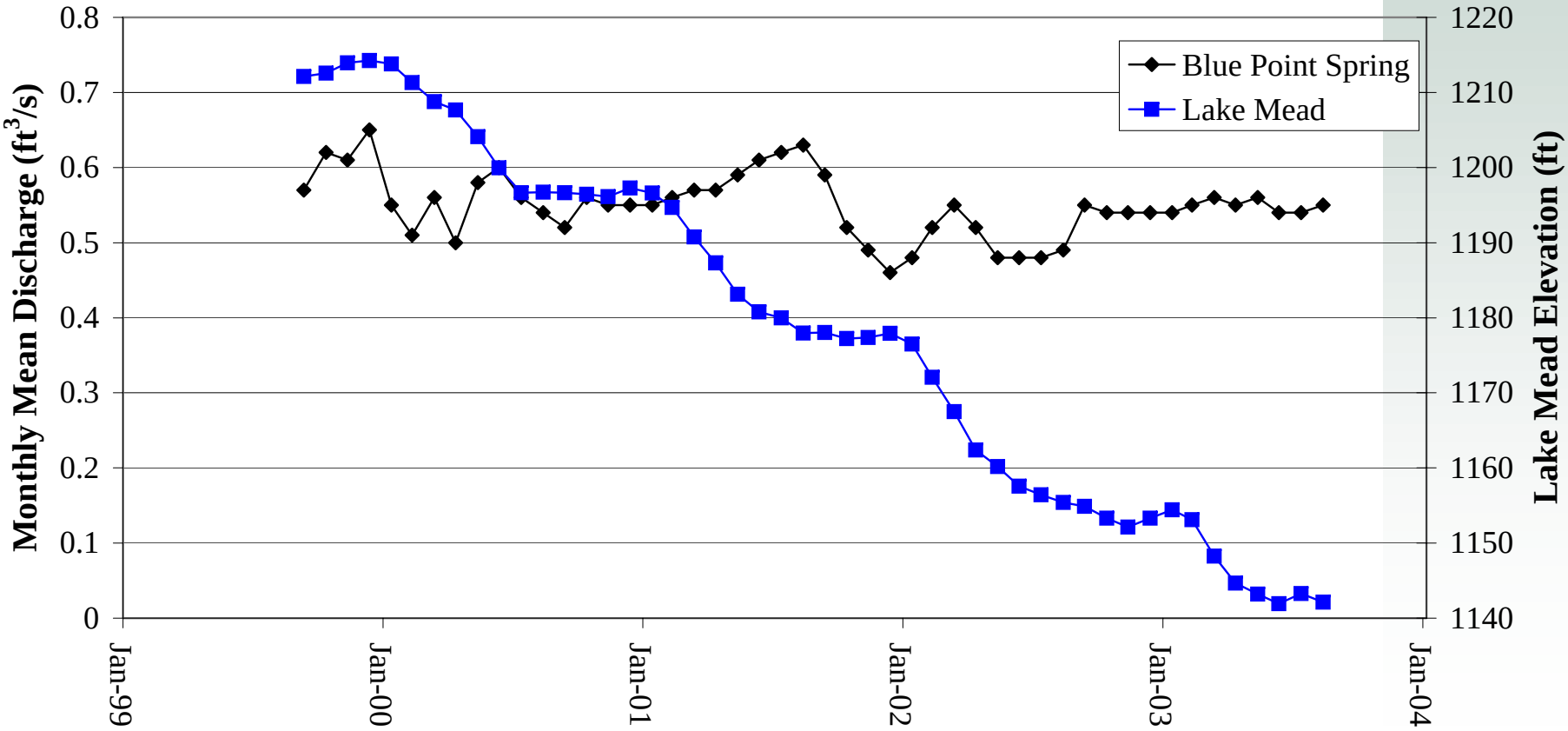
Rogers Spring Discharge 1985-2003



Blue Point Spring Discharge 1999-2003



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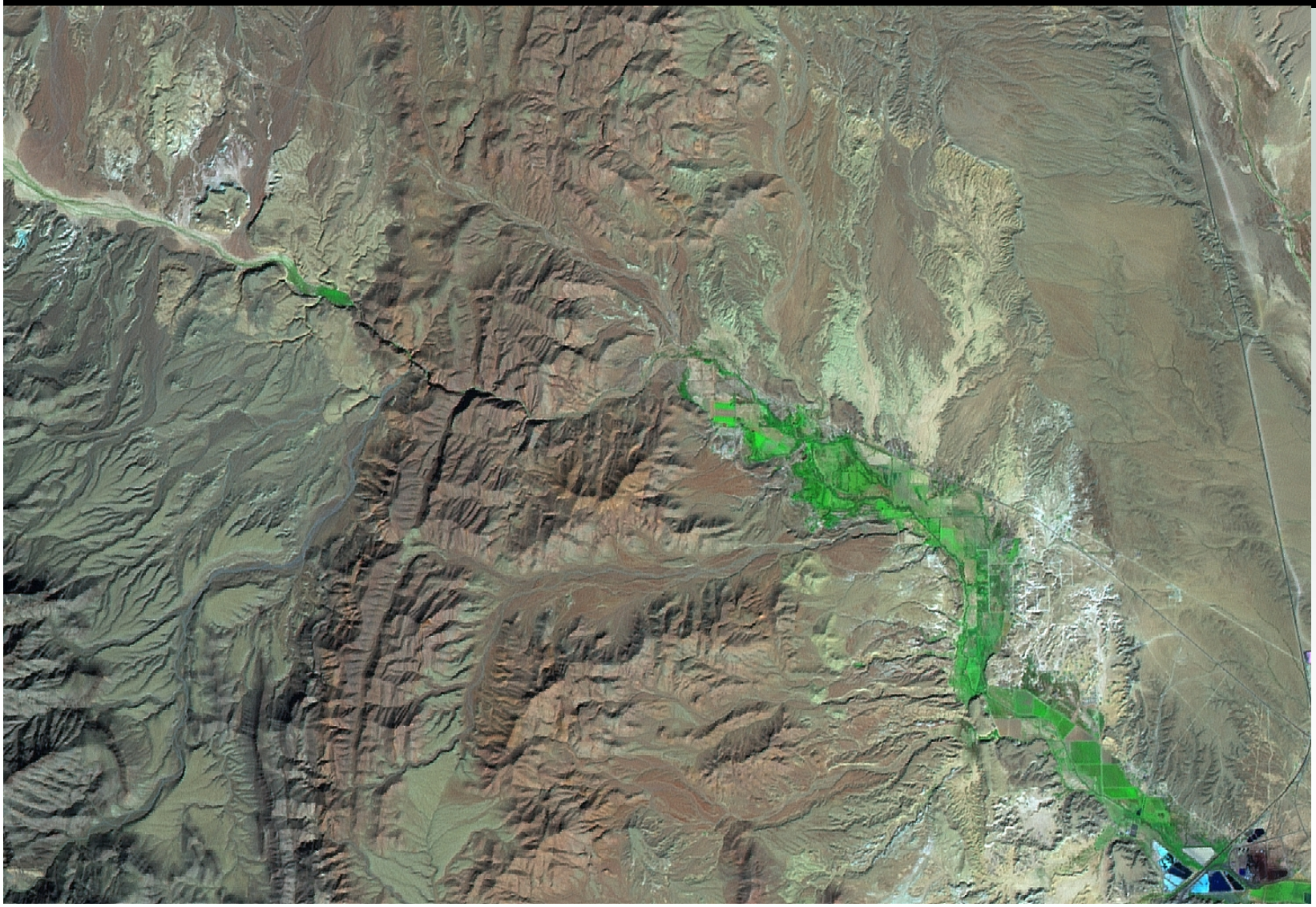

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Groundwater Hydrology 101

- Water balance
  - sources
  - users
- Pipes and reservoirs

Water Sources

- Precipitation is limited, with groundwater recharge primarily derived from snowmelt and stormwater runoff
- Precipitation is greater at higher elevations
- Estimates of basin recharge rates are primarily based on discharge estimates

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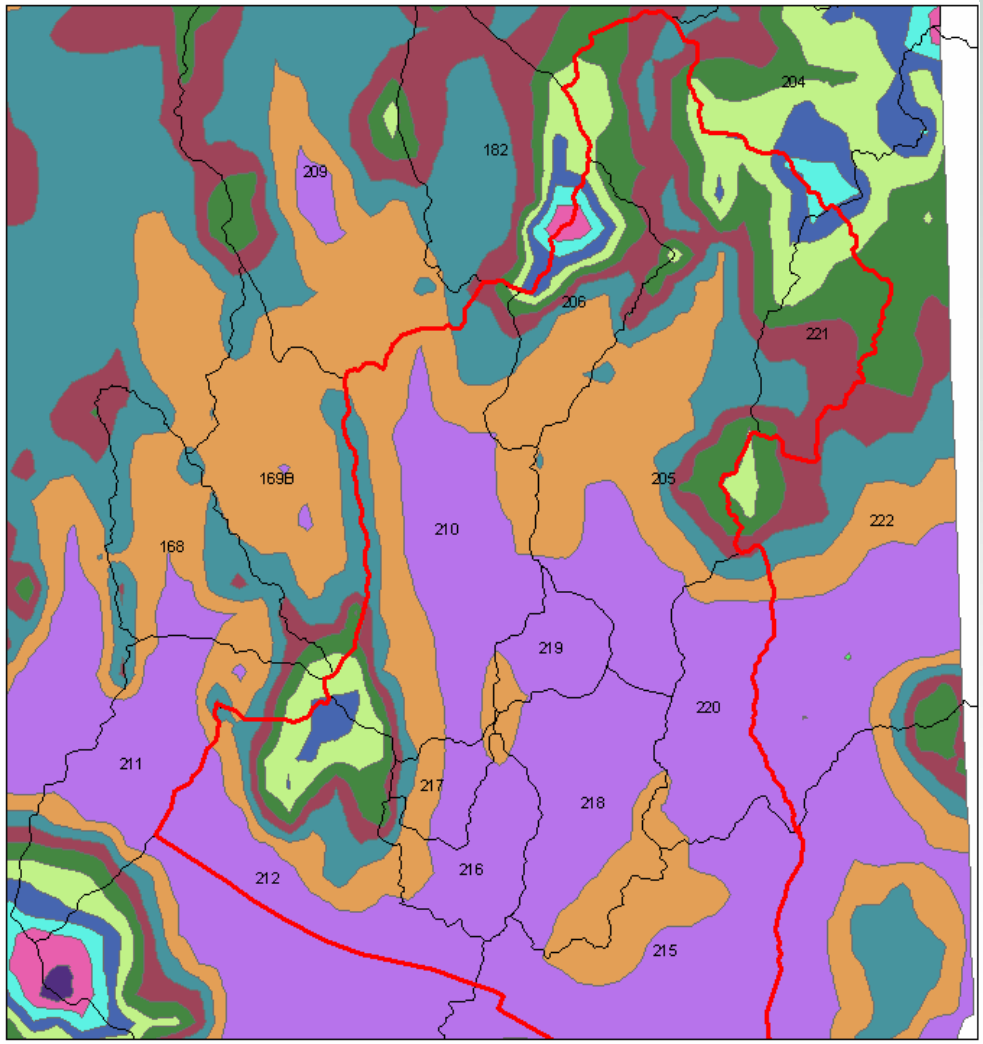
Recharge is estimated as a function of the annual precipitation depth



Pipes and Reservoirs

- Aquifers
  - Paleozoic carbonates
  - Basin-fill sands and gravels
  - Volcanic lavas and tuffs
- Confining beds
  - Proterozoic siliciclastics
  - Fine-grained basin fill
  - Mesozoic clastics

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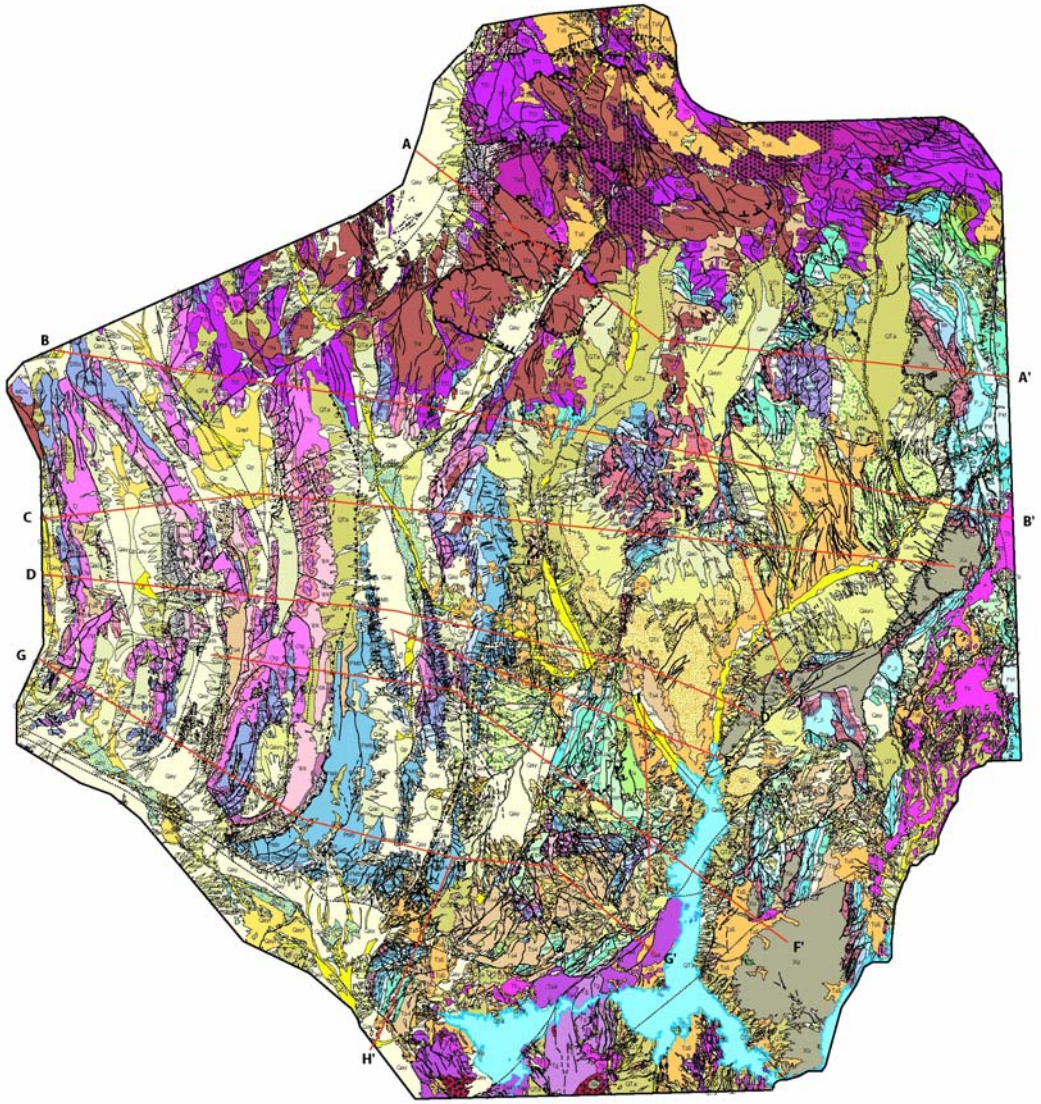
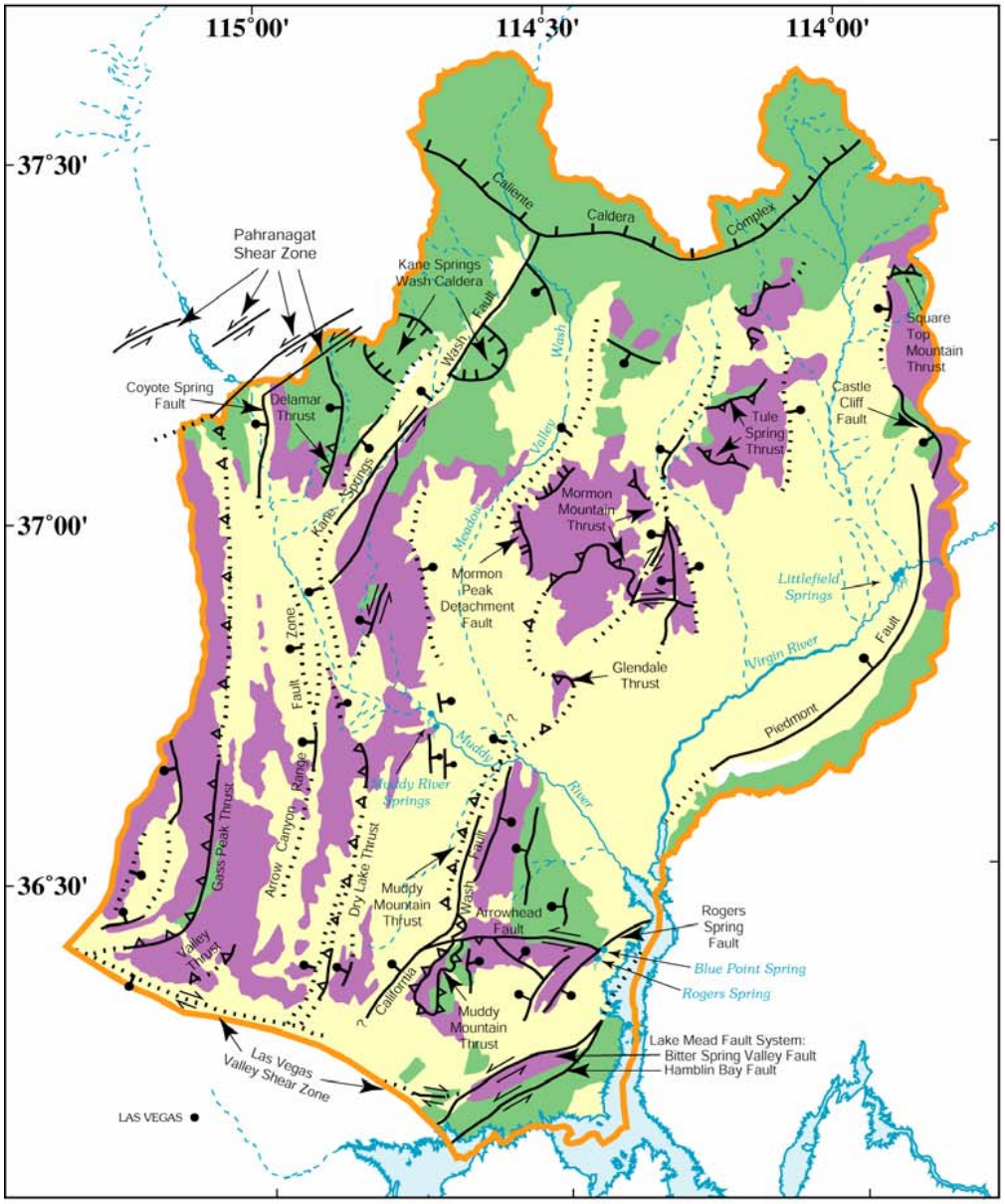
New map being published by Nevada Bureau of Mines, supported by NPS and SNWA



Major Structural Elements and Generalized Hydrogeologic Units



Study Area

High-angle normal fault

Thrust fault

Strike-slip fault

Detachment fault

Oblique-slip fault

Thrust fault reactivated by normal or strike-slip fault

Caldera

Carbonate rocks

Basin Fill

Noncarbonate consolidated rocks

0 20

Miles

Geology modified from Plume and Carlton (1988)

Base modified from USGS digital data, 1:100,000 and USGS GAP Analysis data.

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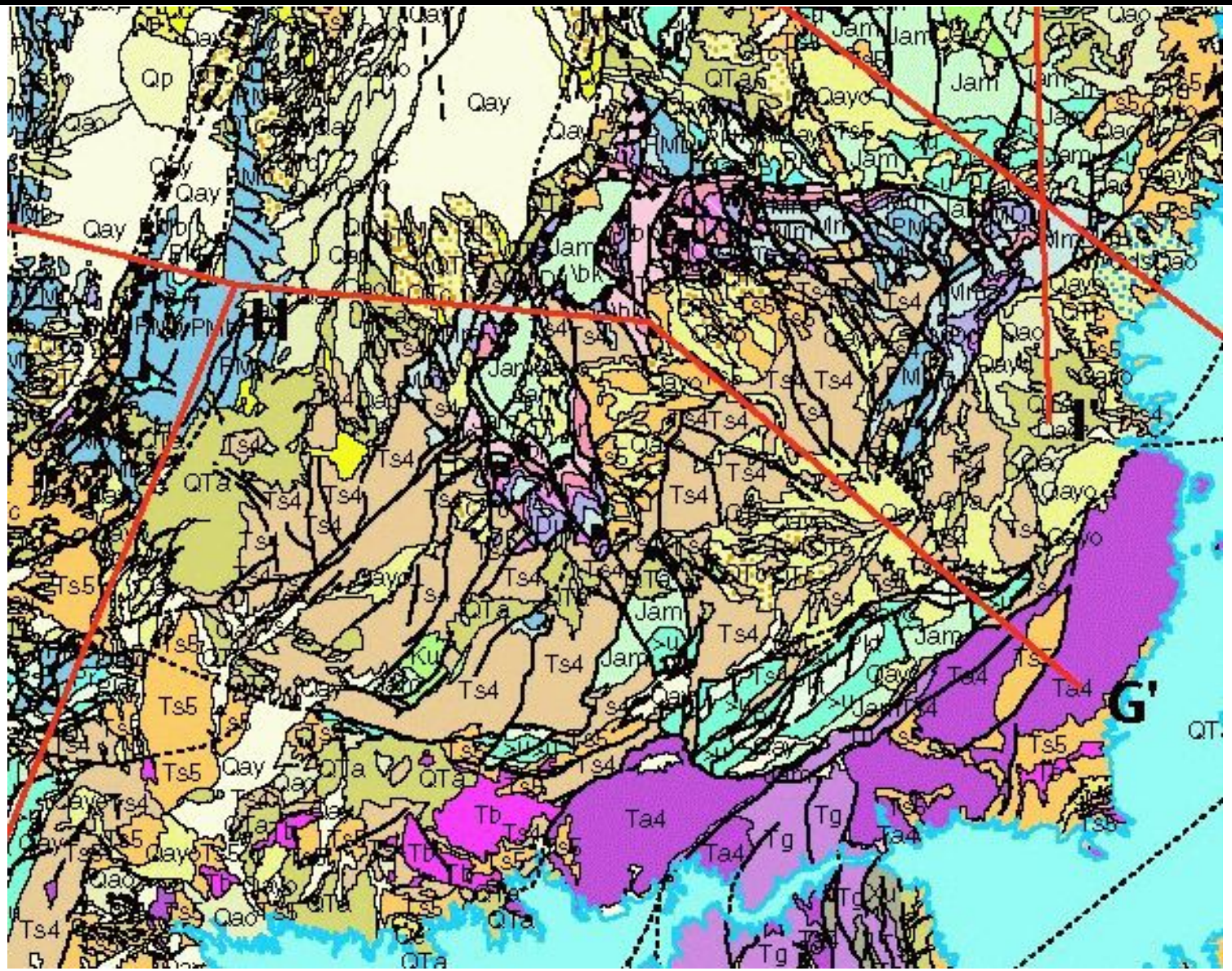

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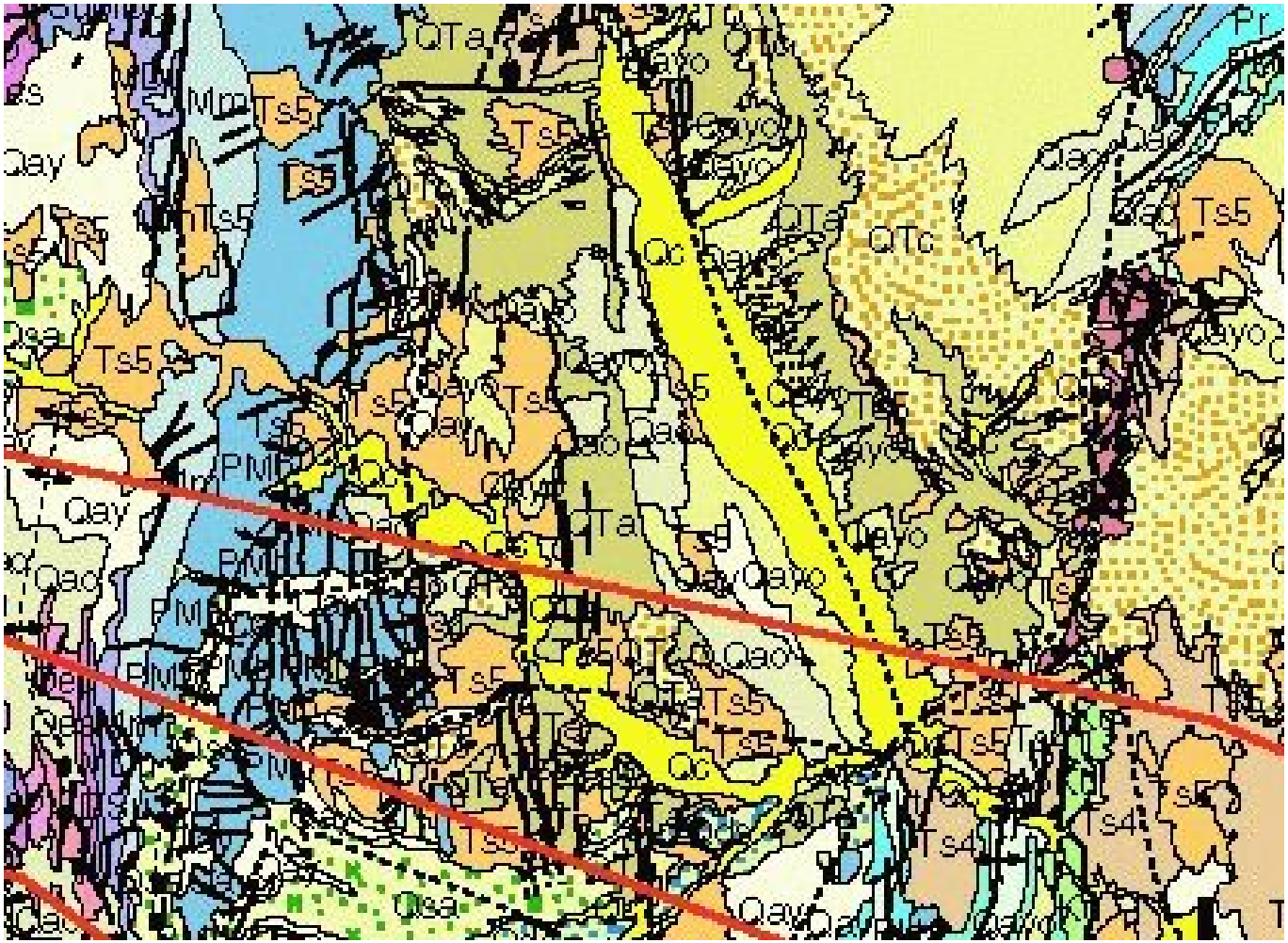

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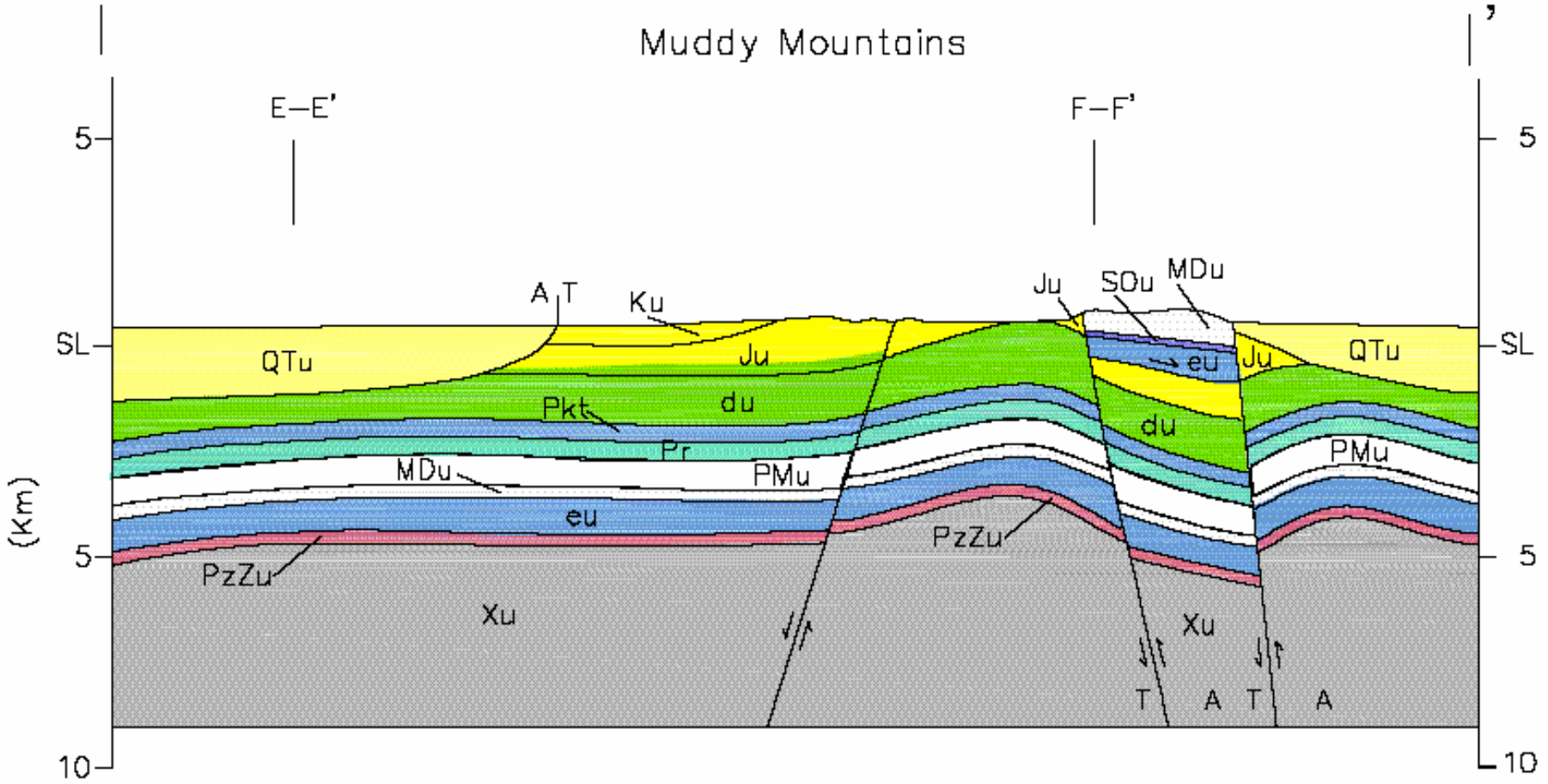

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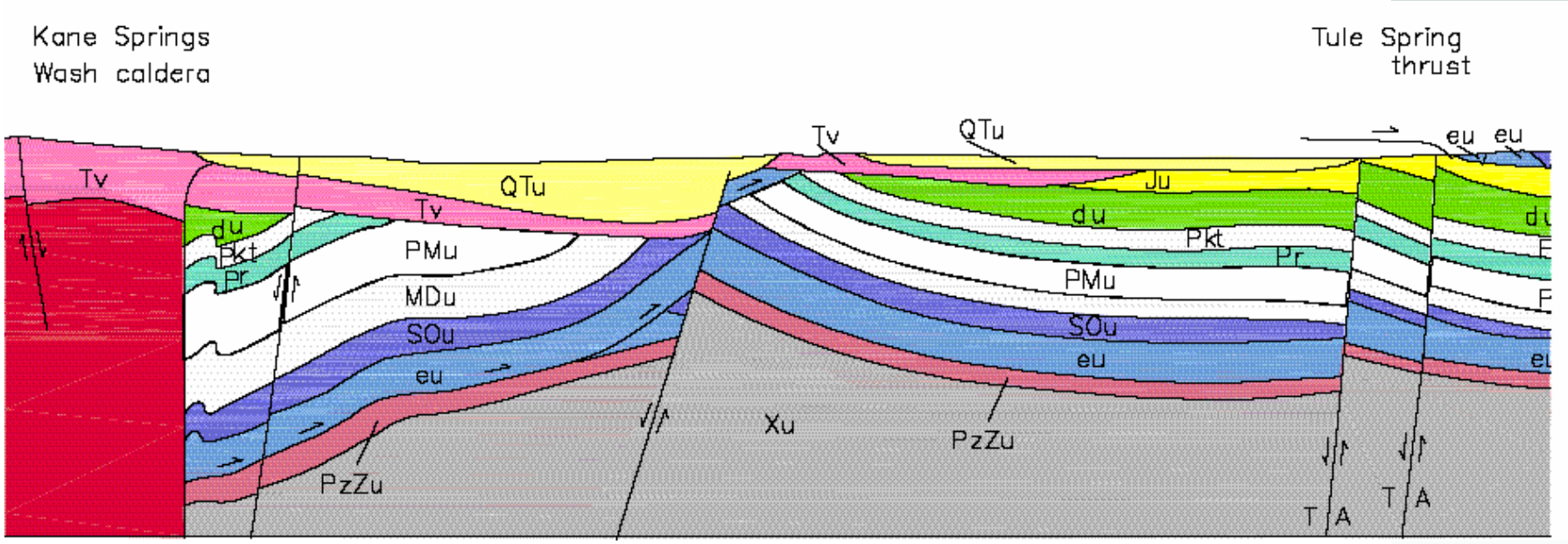

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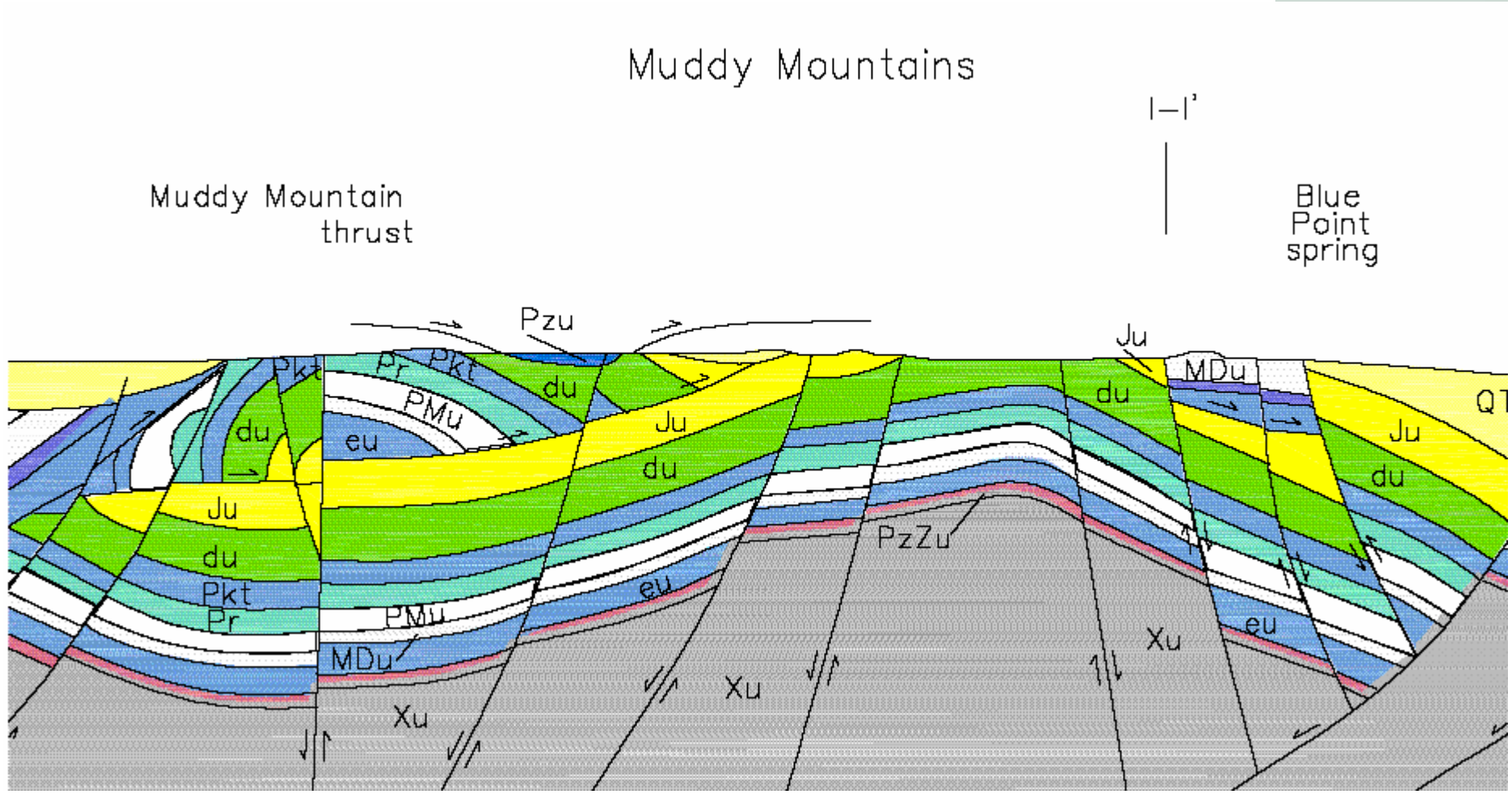

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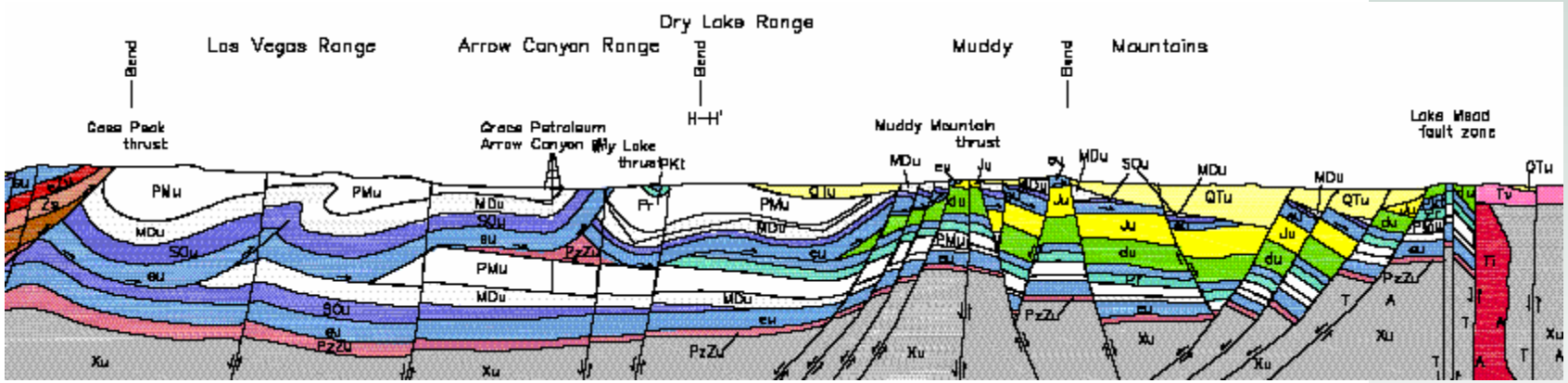

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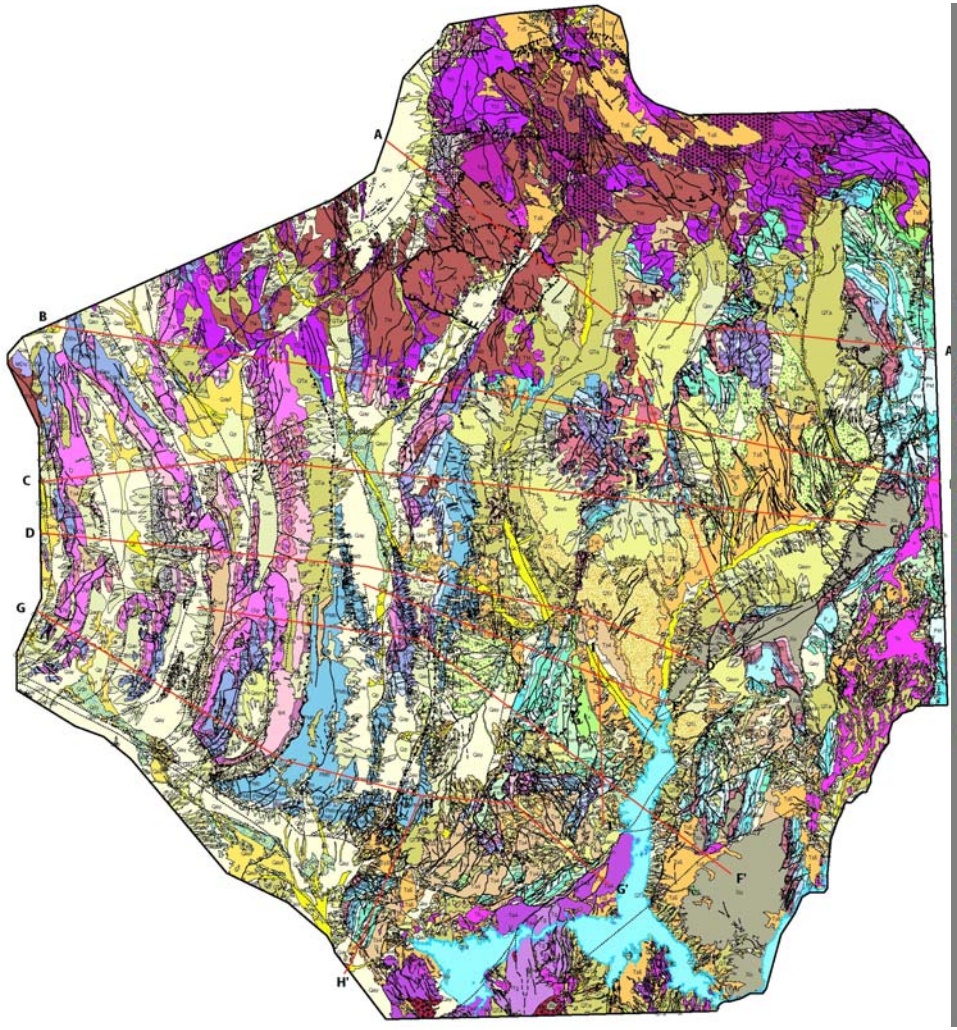

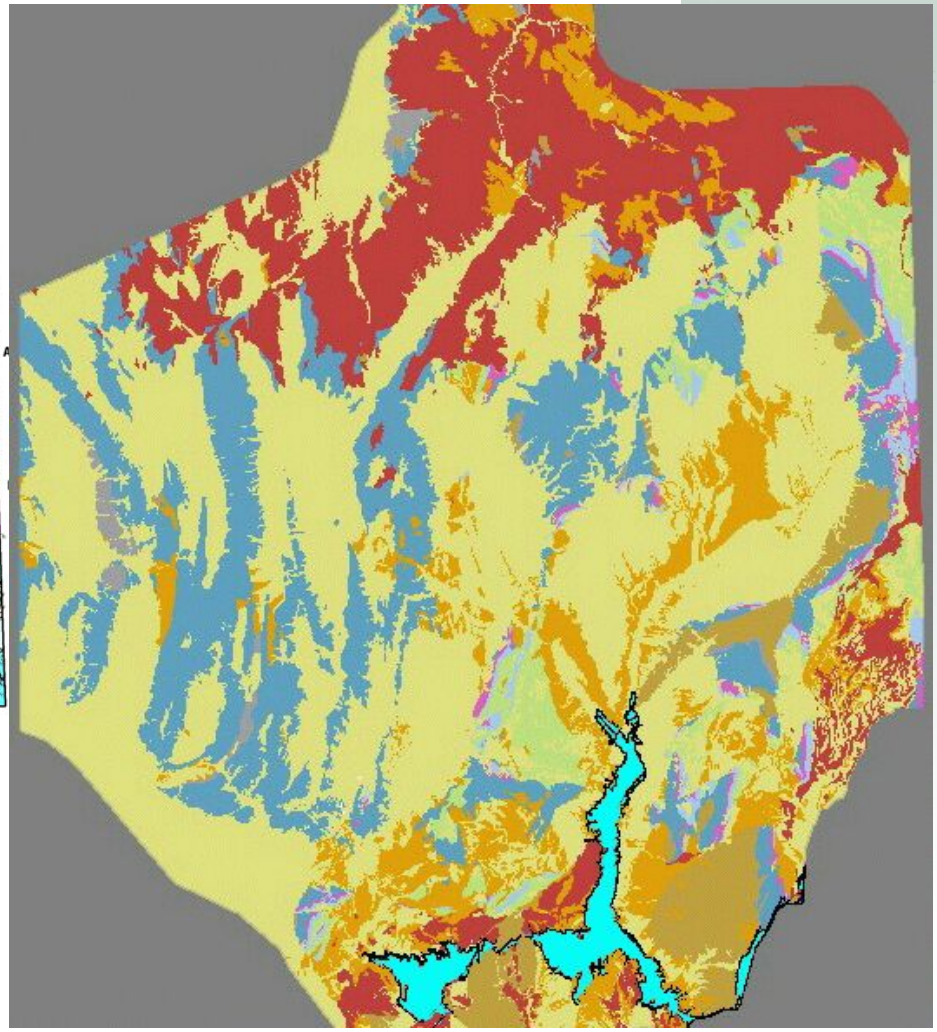

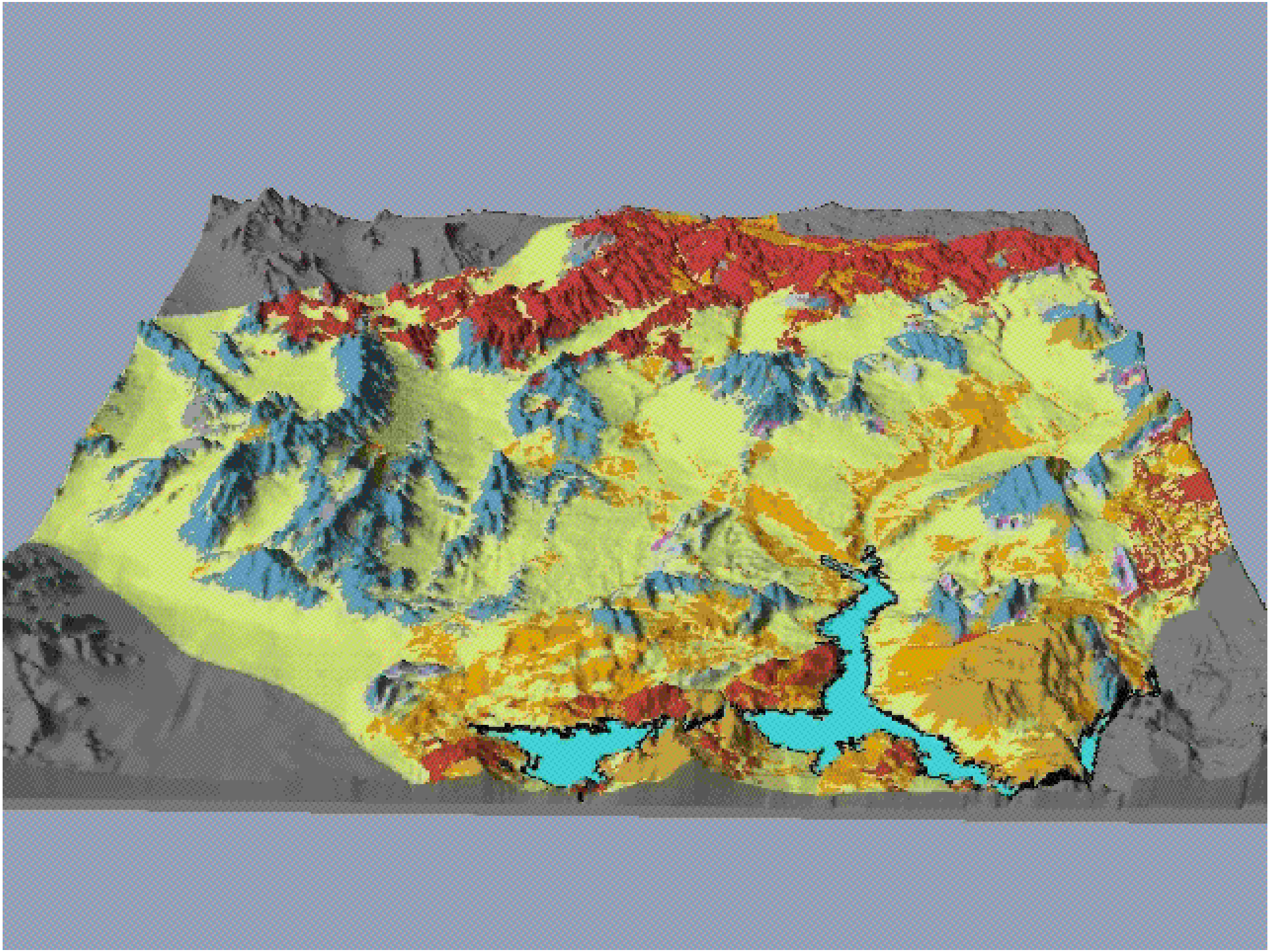

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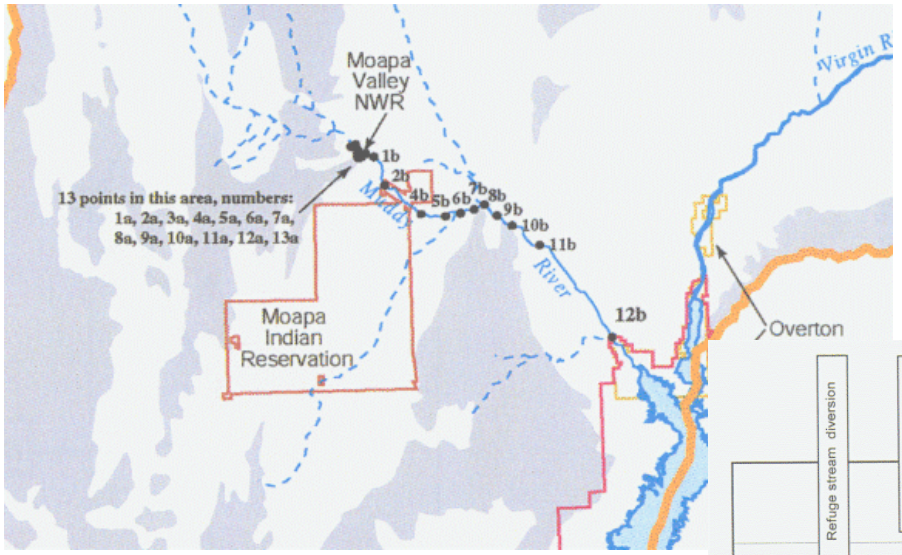
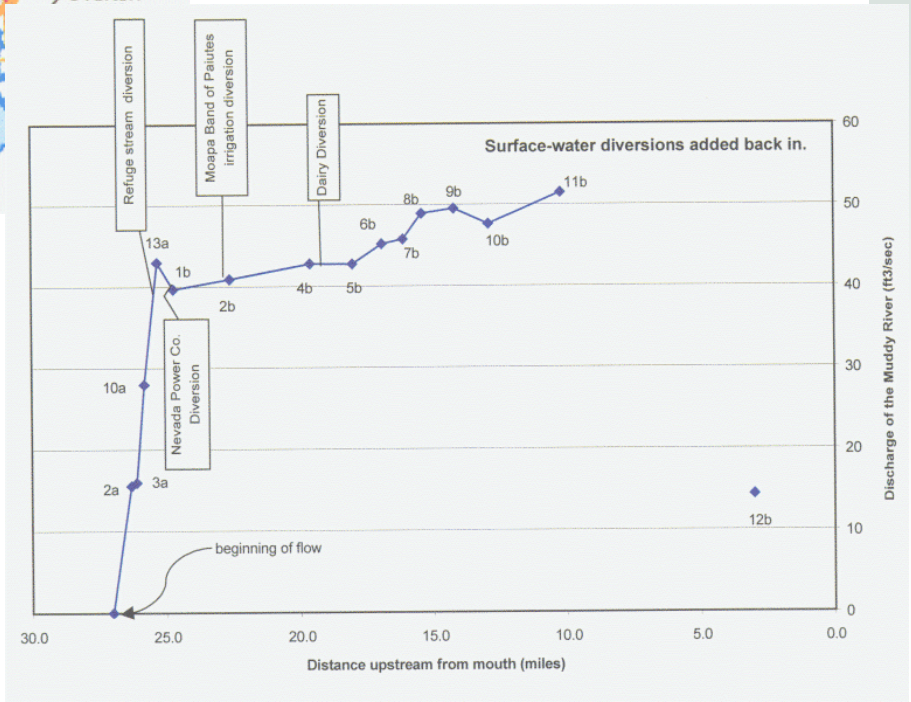


Stream gain-loss studies provide information on both water balance and geologic controls on groundwater flow



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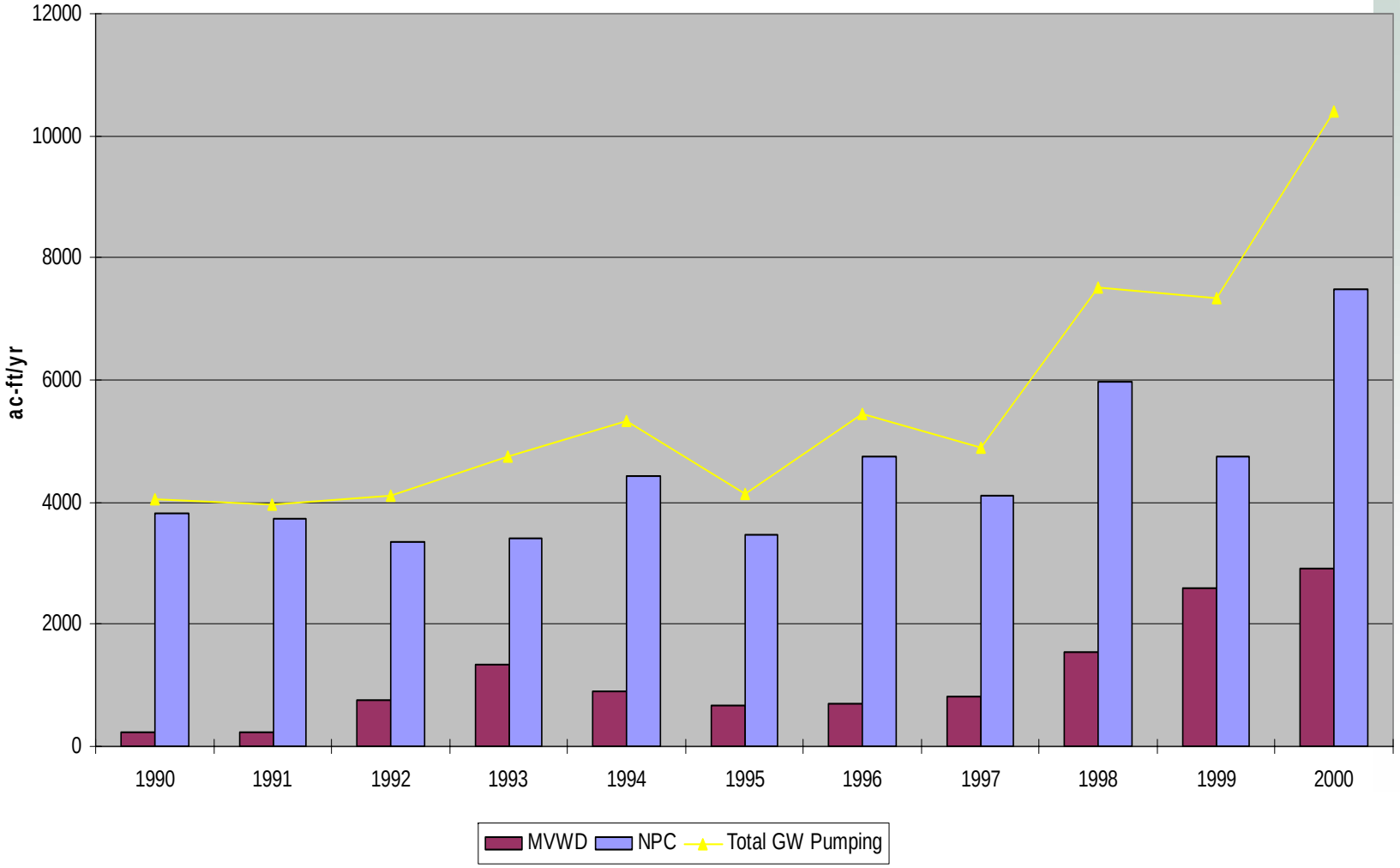
Groundwater Pumping in Muddy River Springs Area



Preliminary Model

- Developed in “emergency” mode for use in water rights hearings during the summer of 2001
- Collaborative effort of NPS and FWS
- Based on geologic datasets developed by DoI contractor in early 1990’s

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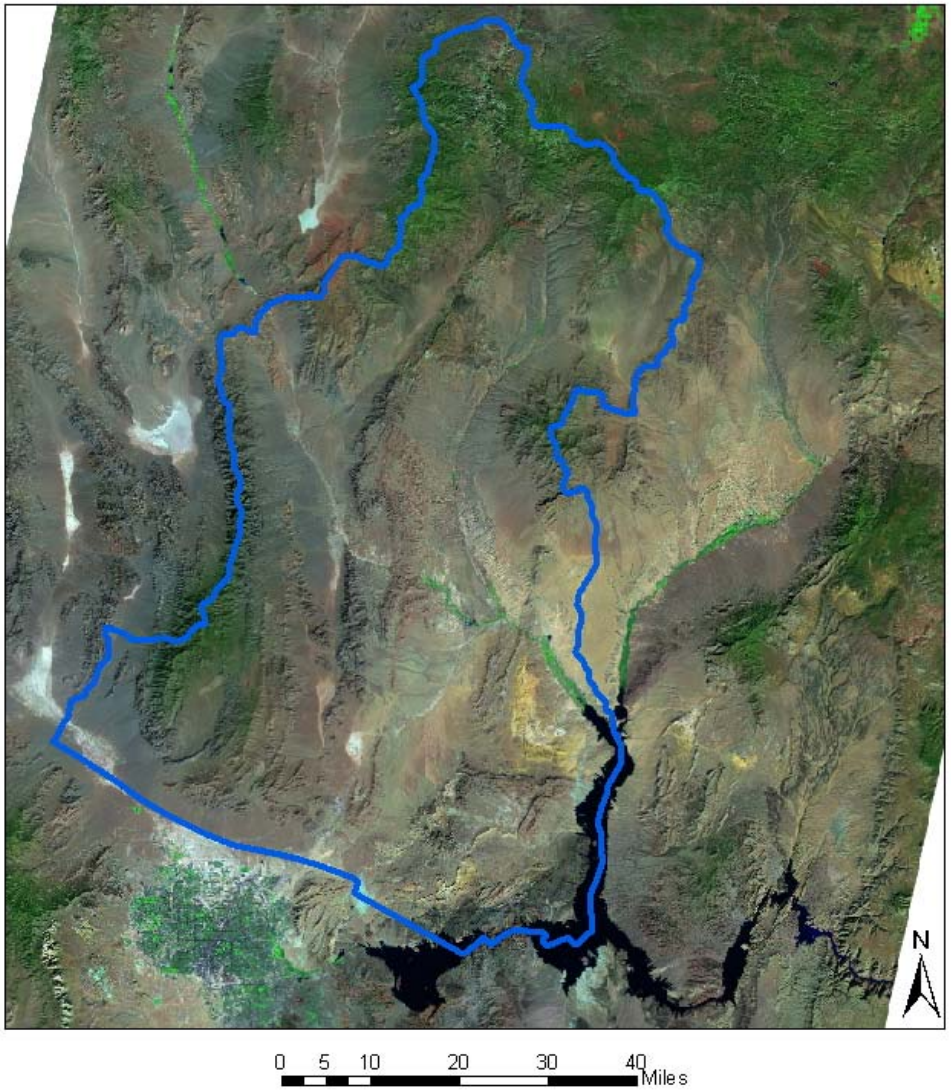
Outline of the Preliminary Model



MODFLOW

- Preprocessors used to develop BCF datasets (currently implemented as the HUF package in MODFLOW-2000)
- Stream Routing package for the Muddy River and associated springs
- DRAIN package for other springs
- GHB for Lake Mead and flux across the Las Vegas Valley Shear Zone
- HFB for barrier faults

Model Calibration

- "Steady-state"
  - Water levels
  - Muddy River discharge
- Pumping
  - Water-level change
  - Decline in Muddy River discharge

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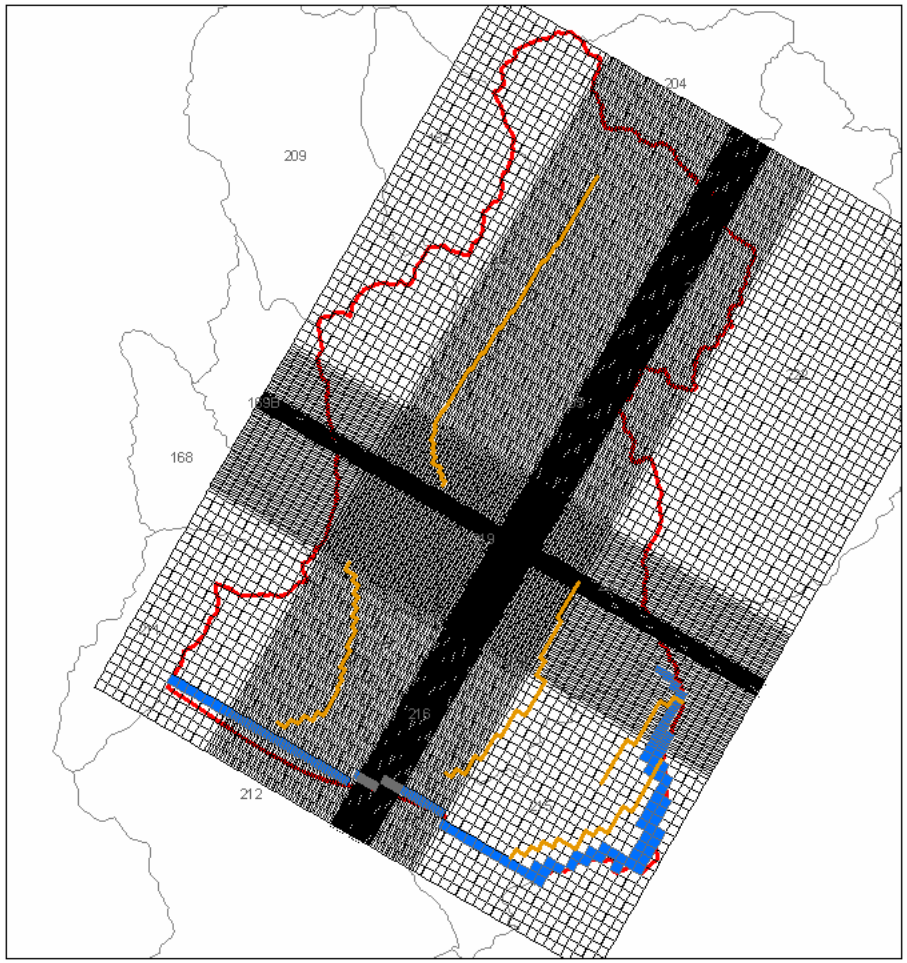

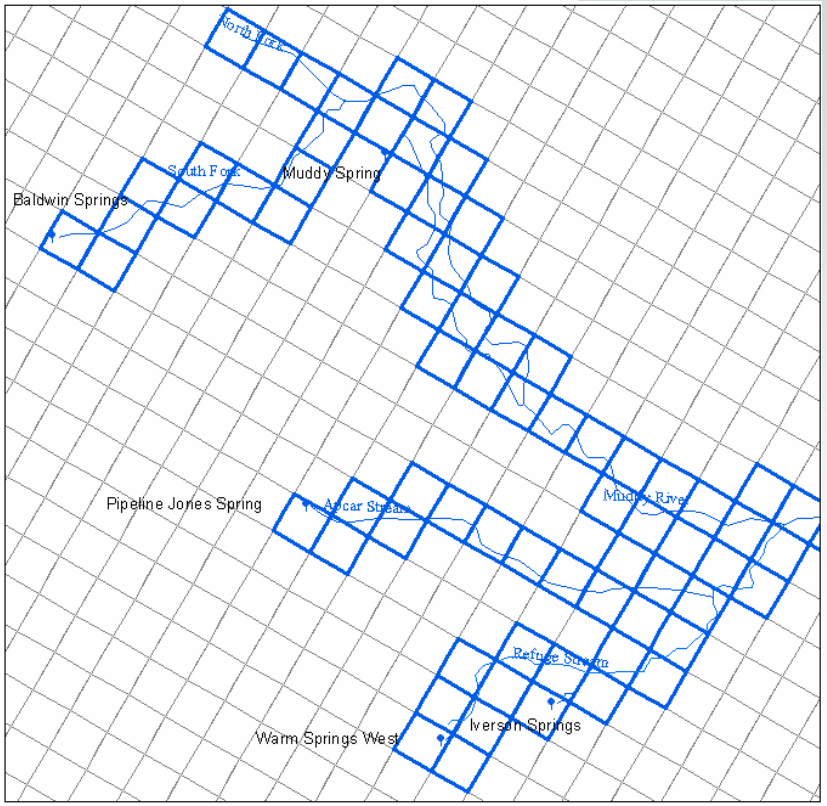

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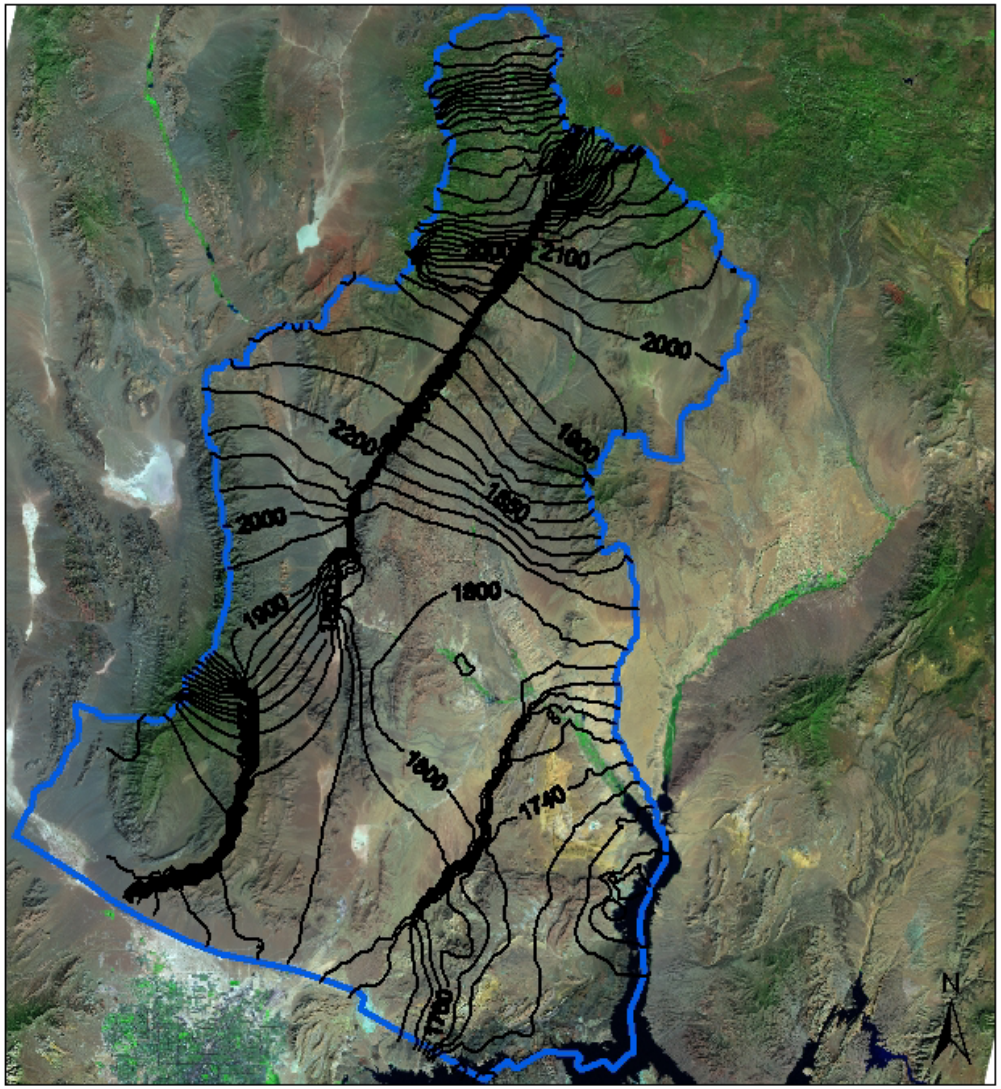
Steady-State Carbonate Water Levels



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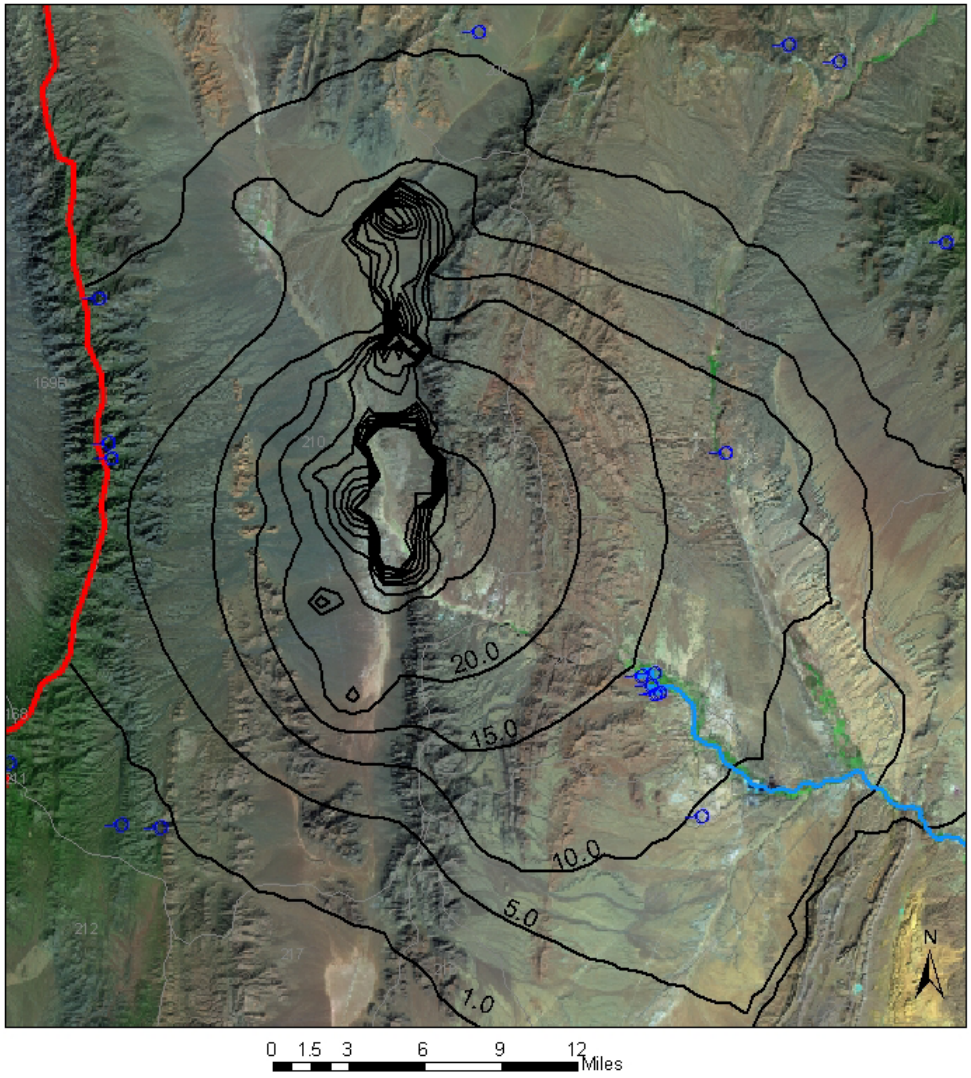
Predicted Drawdown (ft) from CSV pumping, all permits and applications, in 2030



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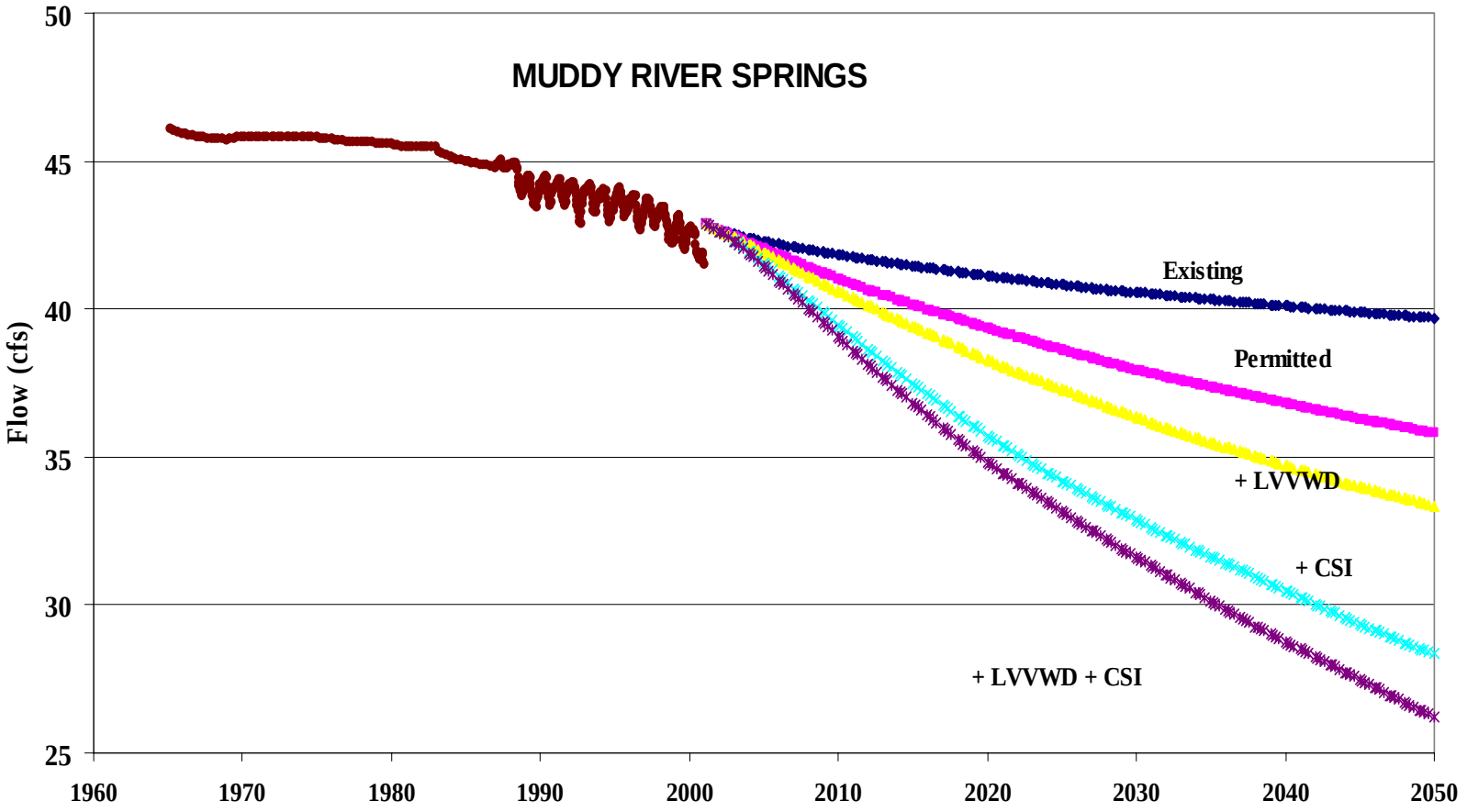

Order 1169

- Separate hearings for applications by SNWA/LVVWD and Coyote Springs Investments
- Nevada State Engineer issued Order 1169, mandating further studies, including a multi-year pumping test in Coyote Springs Valley with monitoring in the Muddy River Springs area
- Separate from a prior agreement between DoI agencies and SNWA

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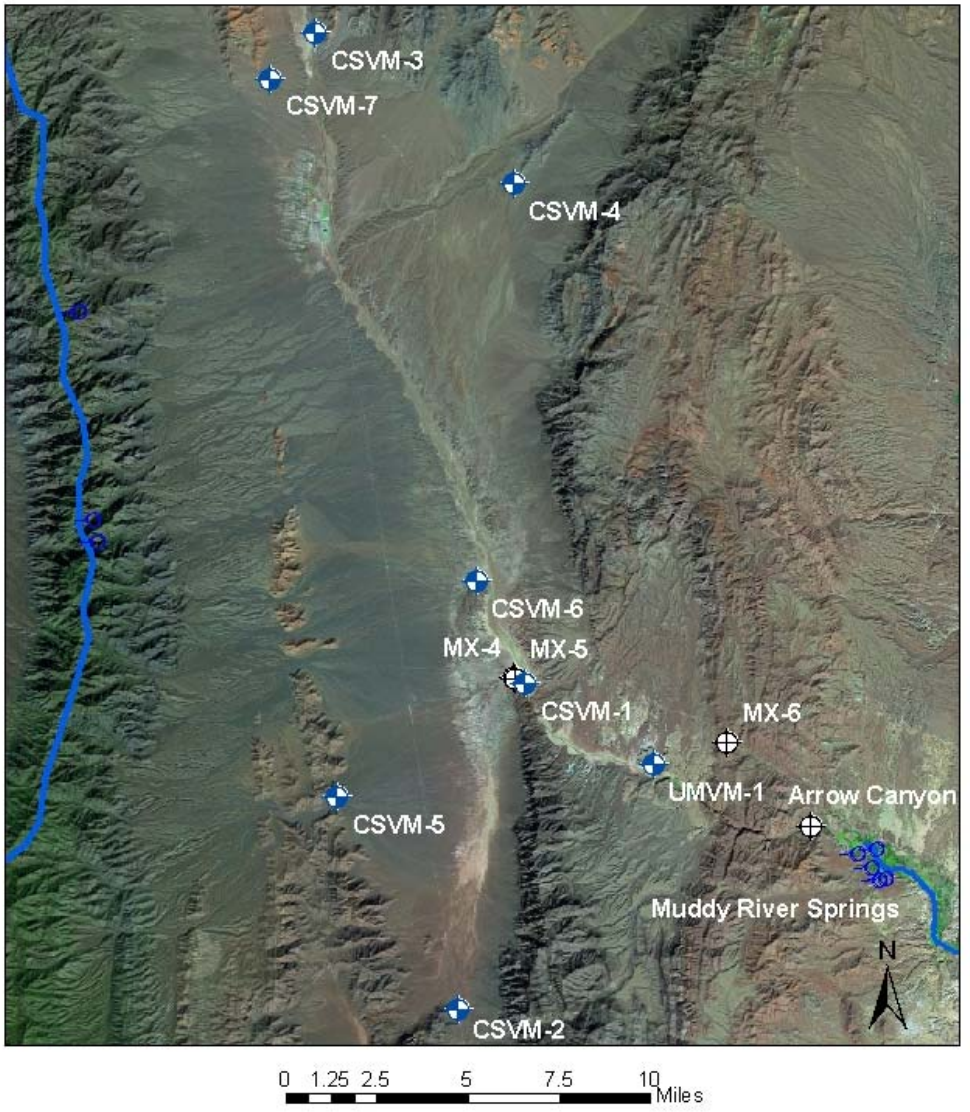
Monitoring and pumping wells associated with the Order 1169 study



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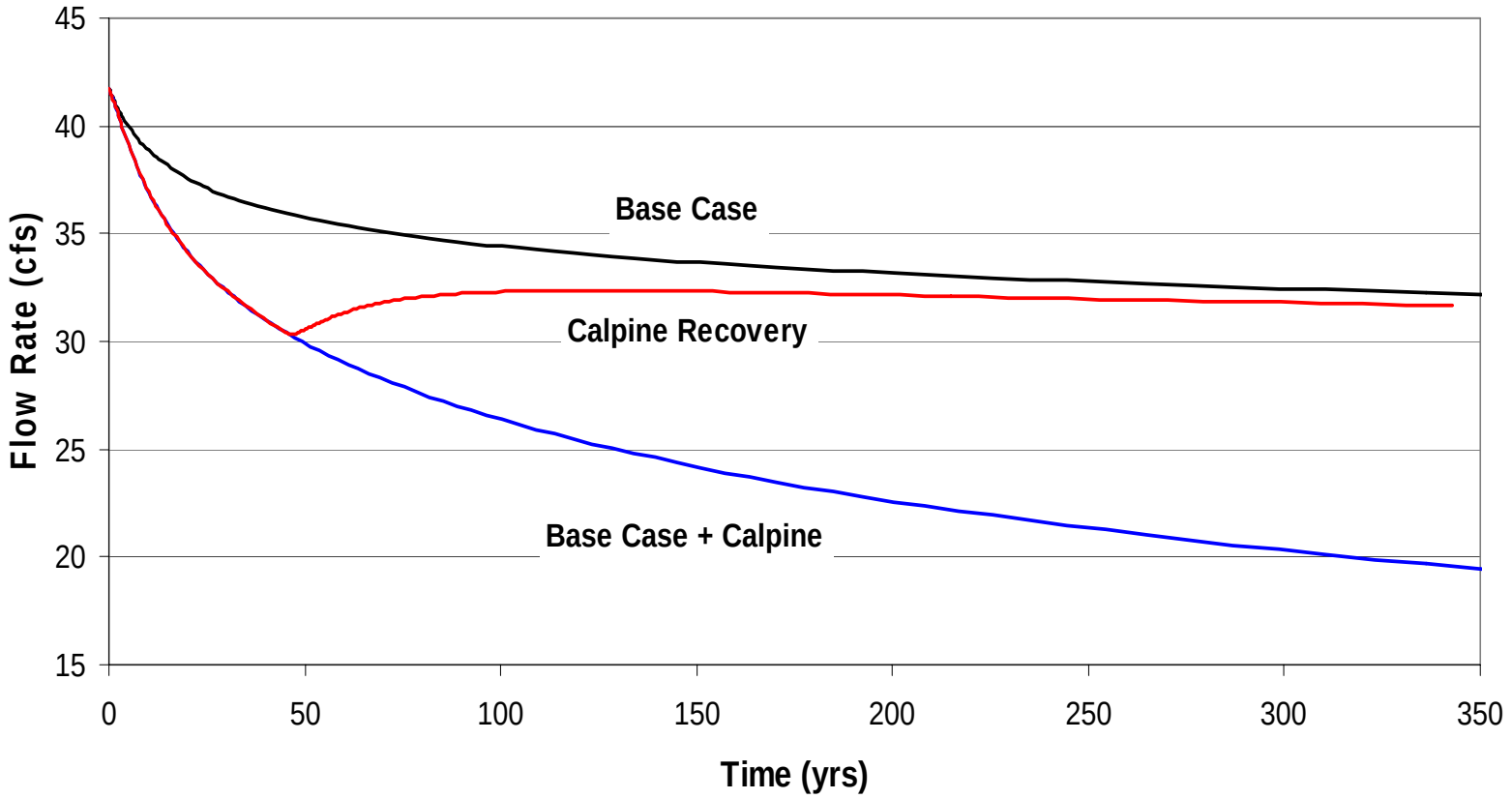
Effects of Calpine Pumping at 20 cfs on Muddy River Discharge



Recent and On-going NPS-sponsored studies

- Geologic framework
- Water budget
- Geochemistry
- Model Development

Geologic Framework

- Geophysics
  - Gravity – data collection and interpretation
  - Seismic reflection interpretation
- Geologic
  - Compilation of a consistent map
  - Cross sections

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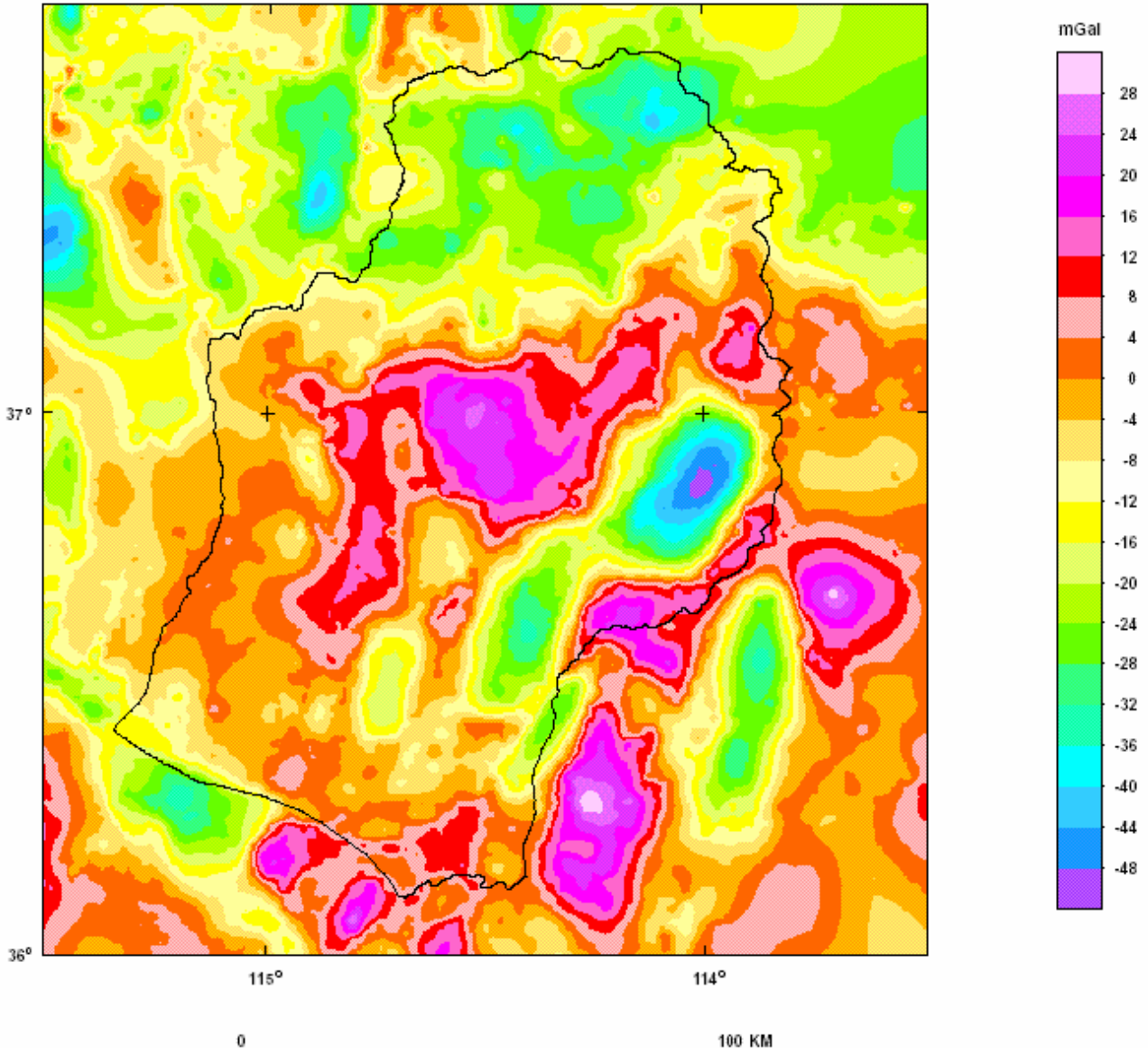
Gravity measurements provide an estimate of the depth to higher density "basement" rocks



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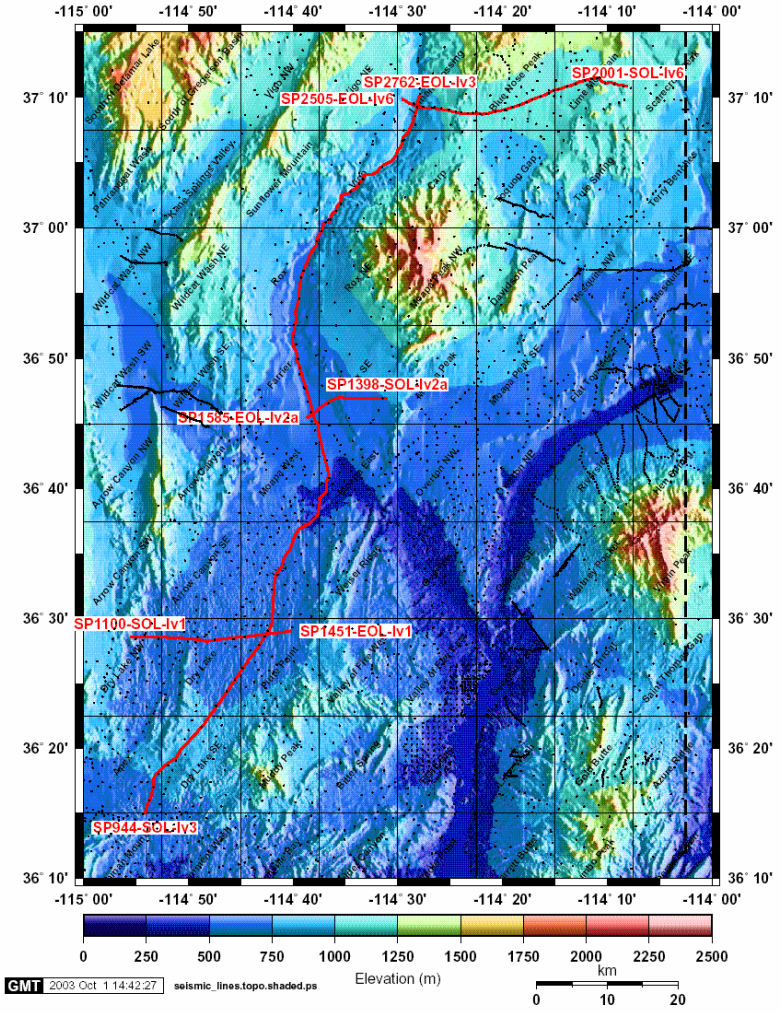
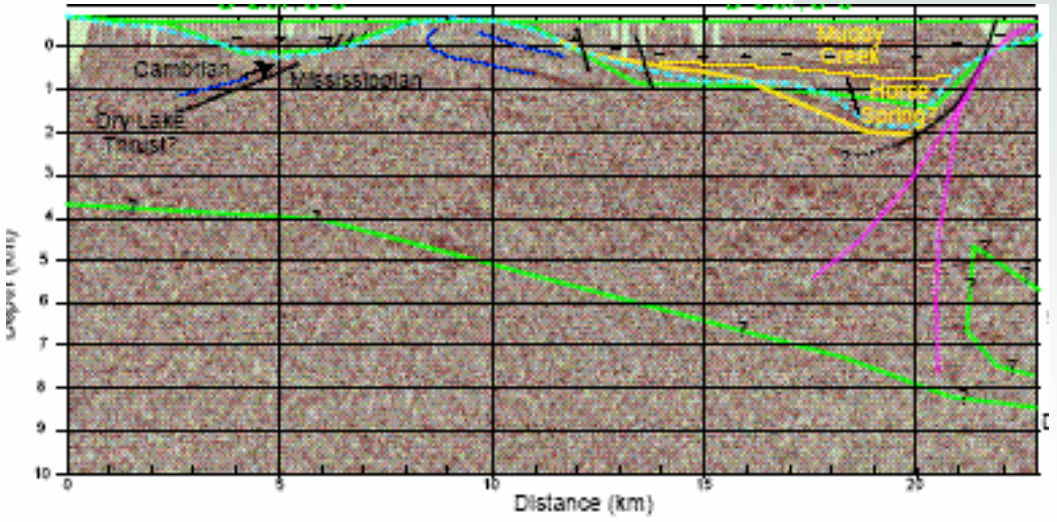
Digitized Seismic Lines -- dots=gravity stations





Water Budget

- Gain-loss studies on Muddy and Virgin Rivers
- Spring discharge monitoring
- Stream flow monitoring on the Muddy and Virgin Rivers
- ET measurements
  - Virgin River
  - Muddy River

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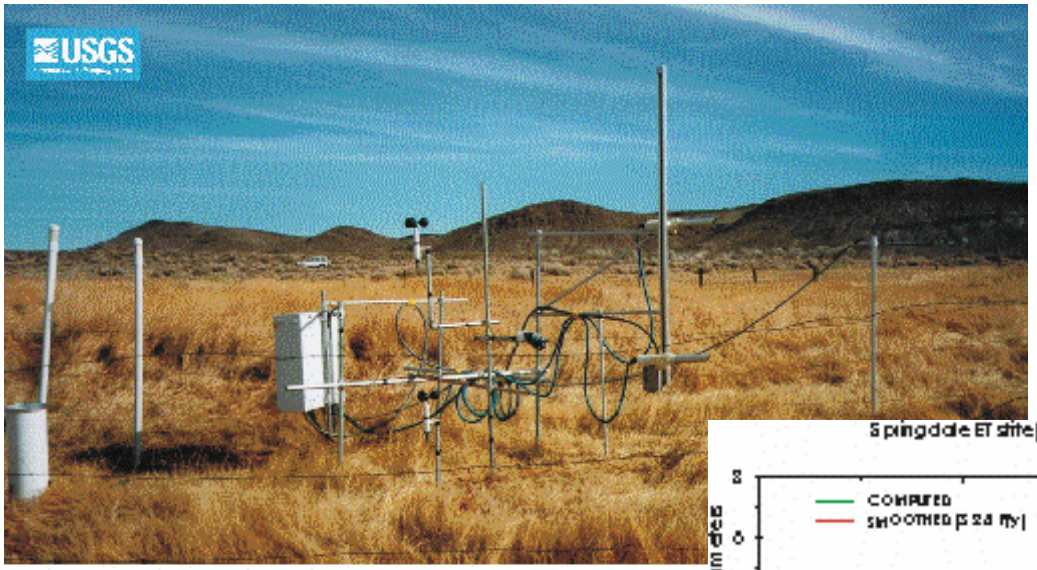
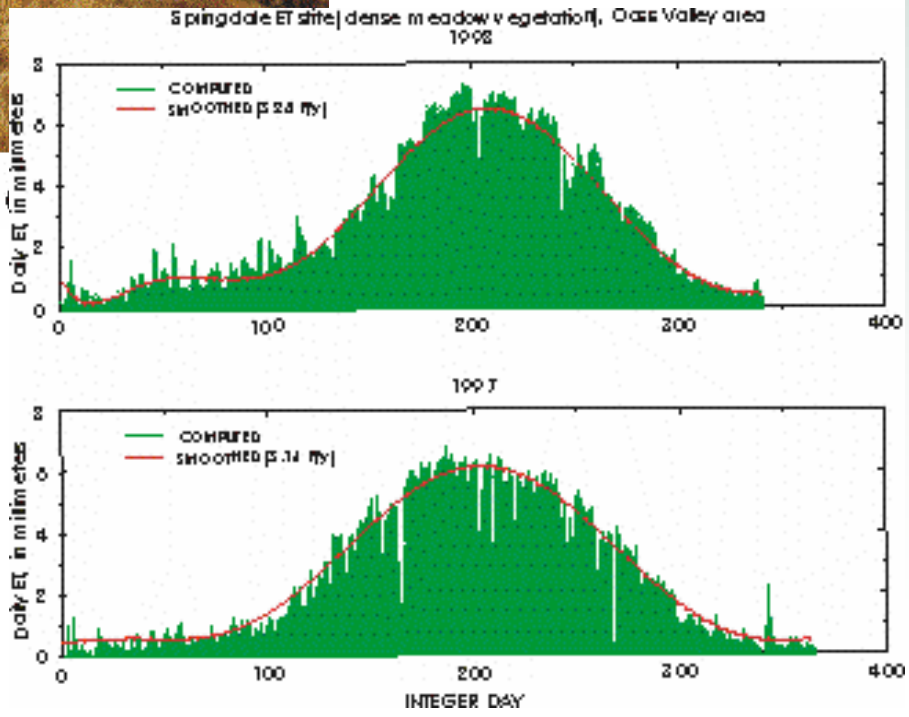


ET Site over dense meadow vegetation,



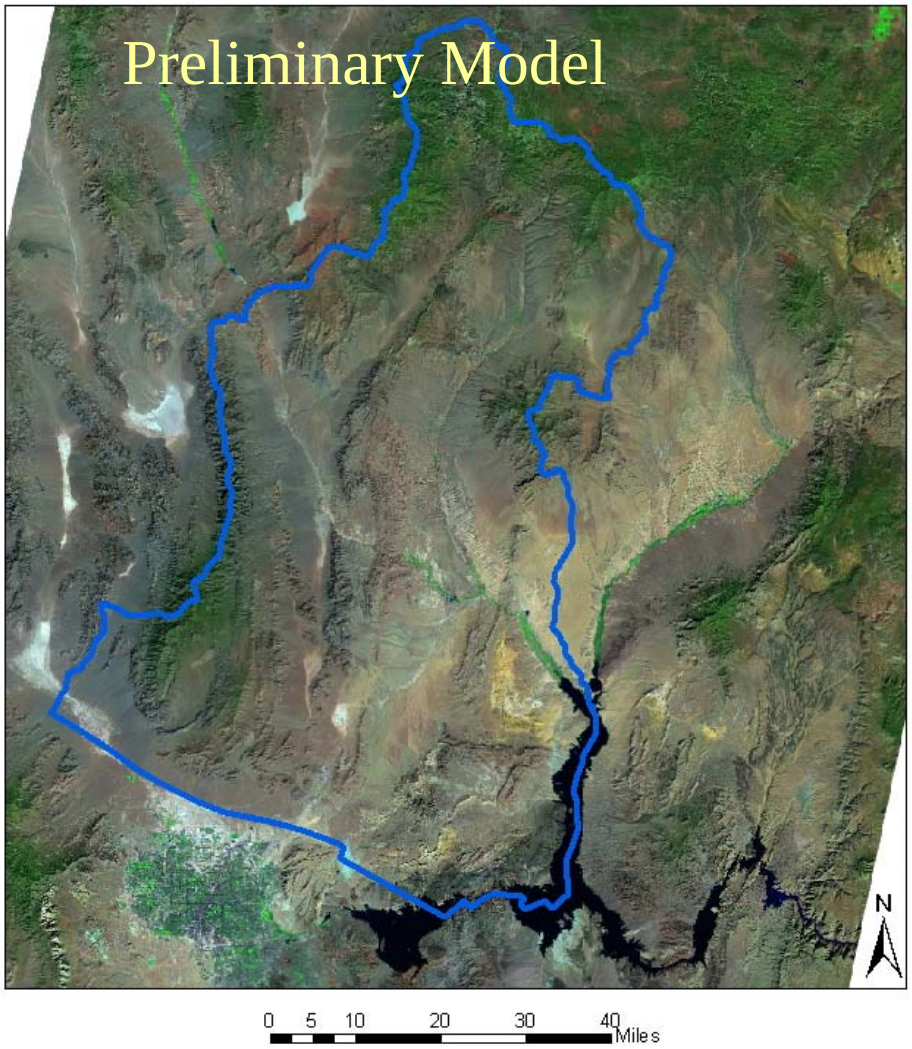
Energy Balance calculations are used to determine the rates of evapotranspiration of different plant communities

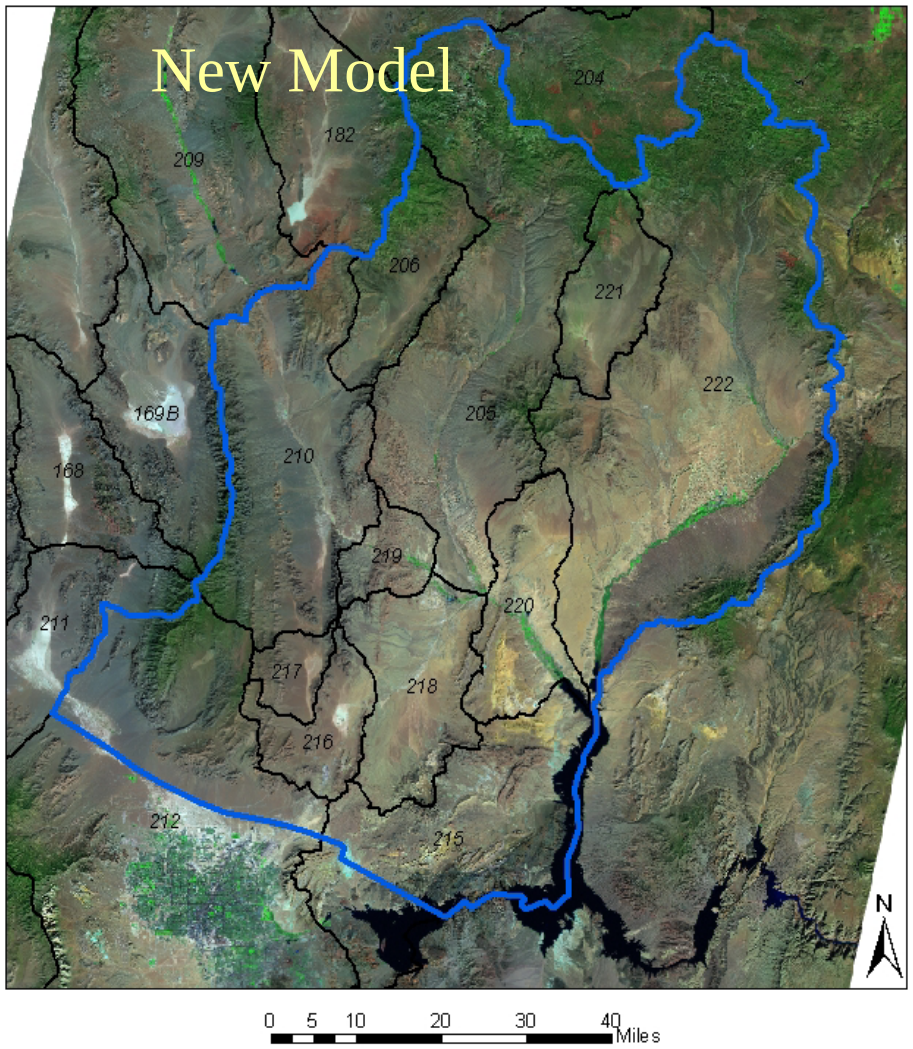
Geochemistry

- Interpretation of existing data to independently estimate flow paths
- Collection of samples from new wells

Model Development

- Construct new geologic framework model based on the recent work
- Enlarge model area to include the Virgin Valley
- MODFLOW-2000


Preliminary Model
N
0 5 10 20 30 40
Miles


New Model
204
182
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0 5 10 20 30 40
Miles

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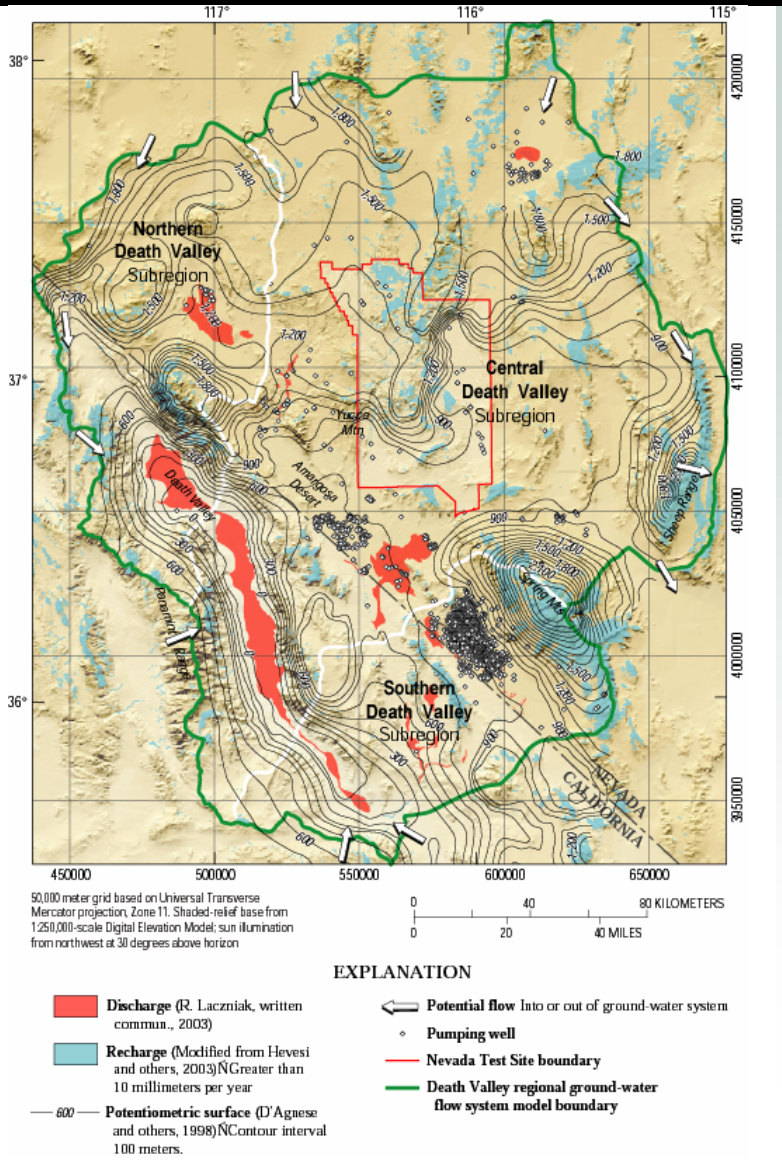
The grid of the new model is being designed to allow coupling to the recently released USGS model of the Death Valley area



Current Status

- Geologic framework model under development
- Water-level and discharge data continually being updated
- Expect to construct model and begin calibration in approximately 6 months

Summary

- A predictive model is being developed as a tool for NPS managers responsible for Park Service resources
  - Long-term predictions
  - Cumulative effects
- Data are needed to decrease the uncertainty in the model predictions, and also serve to increase NPS standing with the Nevada State Engineer